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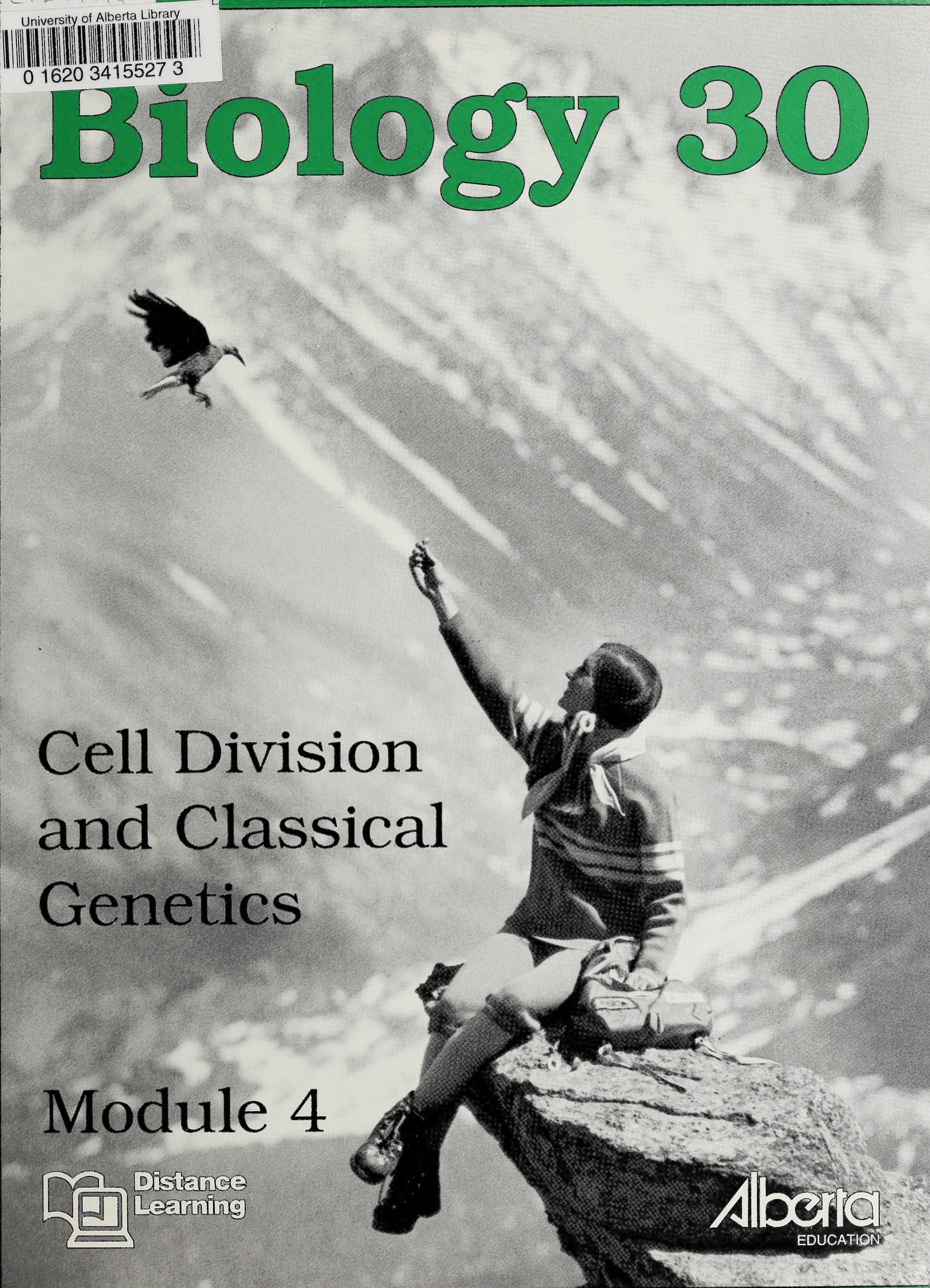

Cell Division and Classical Genetics

Module 4

Distance Learning

Alberta
EDUCATION

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Biology 30

Module 4

Cell Division and Classical Genetics

Distance Learning

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Biology 30
Student Module
Module 4
Cell Division and Classical Genetics
Alberta Distance Learning Centre
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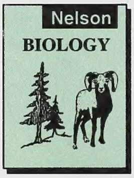
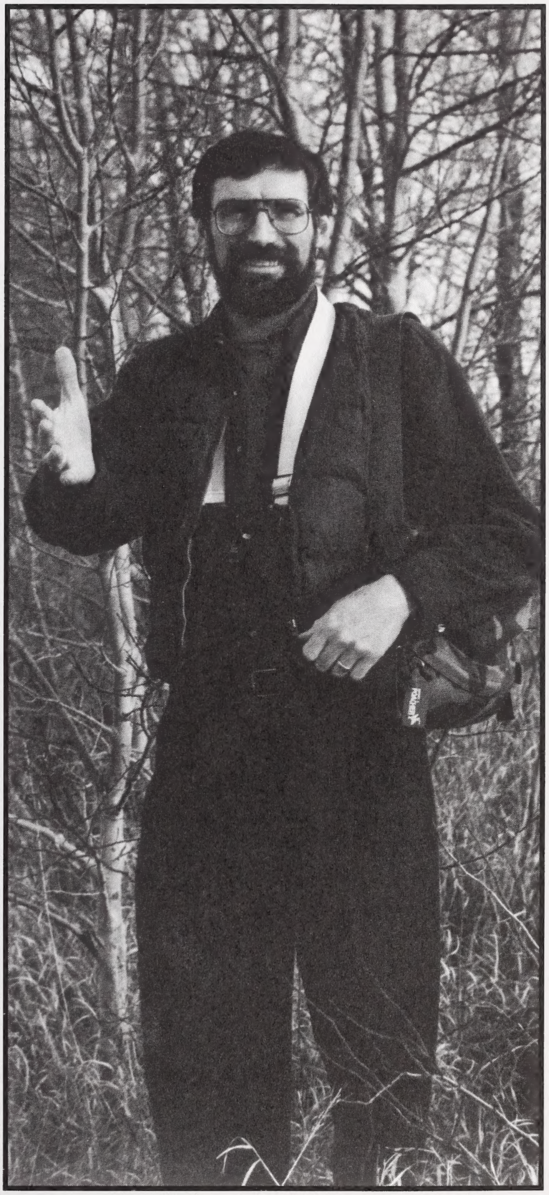
Welcome to Module 4

We hope you'll enjoy your study of *Cell Division and Classical Genetics.* Remember, to make your learning a bit easier, several videocassettes and laser videodiscs are referred to throughout the modules. Your textbook, *Nelson Biology*, will enhance your studies.



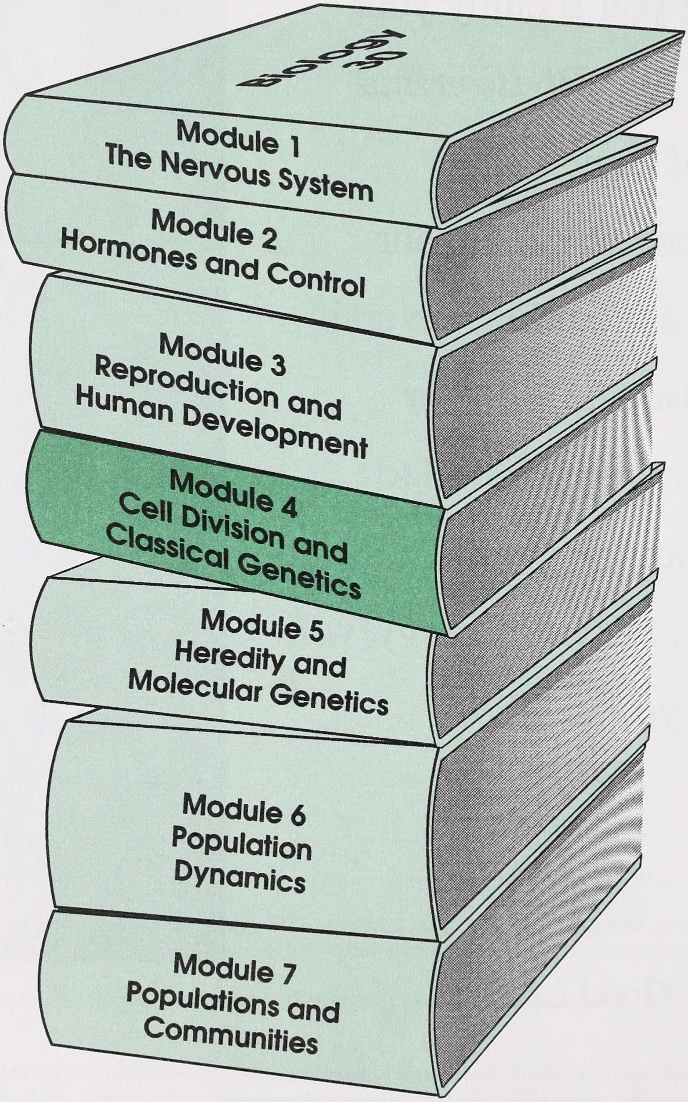
Good Luck!



COURSE OVERVIEW

This course contains seven modules. The module you are working in is highlighted in a darker colour.

Biology 30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Hormones and Control
Module 3
Reproduction and Human Development
Module 4
Cell Division and Classical Genetics
Module 5
Heredity and Molecular Genetics
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Population Dynamics
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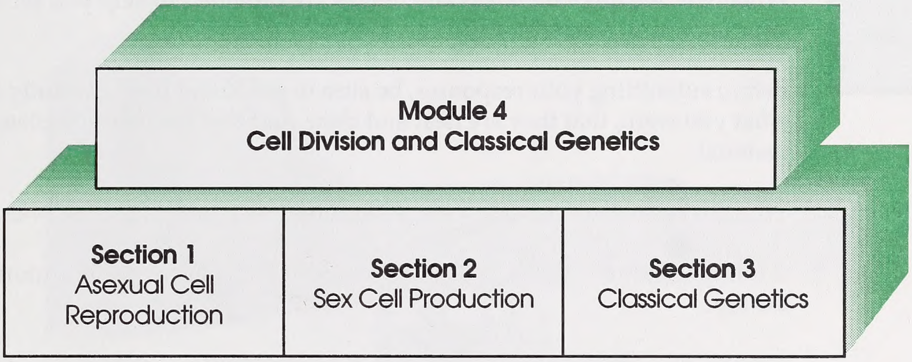
MODULE OVERVIEW

Grandpa Wayne came down the stairs for breakfast on the first day of his visit wearing one red sock and one green sock. He couldn't understand why his daughter Susan and her husband were both giggling as they looked at him. When Susan's young son Robert appeared to miss the joke, Susan pointed to Grandpa's socks.

Grandpa Wayne shrugged off his mistake, but Robert still could not understand what the commotion was all about. He went back to playing with the adhesive bandage on his knee. The sudden realization that her son was likely red-green colour blind, just like his grandfather, made his habit of removing adhesive bandages seem insignificant to Susan at that moment!

In this module you will study the biology behind this story. You'll explore cell reproduction associated with the conception of Robert, the repair of Robert's knee, and the growth of Robert until he reaches adulthood. Mechanisms of inheritance will be studied that will explain how Grandpa Wayne's colour blindness skipped a generation and appeared in Robert. The basic rules of genetics will explain this question and will help you to understand some simple patterns of inheritance that commonly occur in all organisms. Like Gregor Mendel, the father of genetics, you will learn to predict the chance of inheriting a certain trait.



Evaluation

Your mark in this module will be determined by how well you complete the assignments at the end of each section. You must complete all assignments. In this module you are expected to complete three assignments. The mark distribution is as follows:

Section 1 Assignment	**30 marks**
Section 2 Assignment	**30 marks**
Section 3 Assignment	**40 marks**
TOTAL	**100 marks**

When doing your assignments, work slowly and carefully. If you are having difficulties, go back and review the appropriate section.

Read all parts of your assignment carefully. Plan and do your rough work on your own paper. Revise and edit your responses; then set up your final copy for submission on your own paper. Lined looseleaf is recommended. Make sure your answers are neat and organized, with wide left margins and space for teacher comments after each assignment.

Response Page Setup

When you see this icon, ideas and details are provided to help you set up and organize your answer in a certain way.

Before submitting your responses, be sure to proofread them carefully to ensure they say what you want, that they are neat and clear, and that they are complete and missing no material.

You will be submitting **only** your **assignment response pages** for evaluation.

It is important to number and clearly identify each page with this information placed at the top.

Biology 30 – Module 4   Section # Assignment   Page #   Name and ID #

Notice that for some assignment questions two marks are given for communication. This is indicated at the end of a question. For two marks your response should clearly and logically answer the question and show strong linkages between cause and effect. Your answer should consist of complete sentences and use appropriate scientific terminology. Diagrams may be an appropriate part of your answer. An answer that requires more than one reading to be understood because it has only weak linkages between cause and effect and contains inconsistencies may only be awarded one mark or less.

SECTION 1 Asexual Cell Reproduction

Can you imagine losing your arm in a freak accident? That's what happened to a man while working in a gravel pit on a cold December day in 1988. He had hoisted himself up on to a muddy conveyor belt and yelled to his supervisor to turn the machine on so it would be easier to clean. The next thing he remembers is being sucked into the pulley and caught against the frame. The man managed to pull himself free and walked out of the pit carrying his arm. As he was loaded on to a stretcher, the arm slipped and fell to the ground stretching to its limits the small bit of tissue that still held his arm to his body.

Incredibly the arm was reattached by plastic surgeons in a gruelling operation; bone, nerves, muscles, and tendons all had to be rejoined. The healing process has gone on for several years and, after many operations, this man still lacks complete sensation in his arm and can do very little with it. So far about fifty percent function has been regained, but further recovery may be unlikely.

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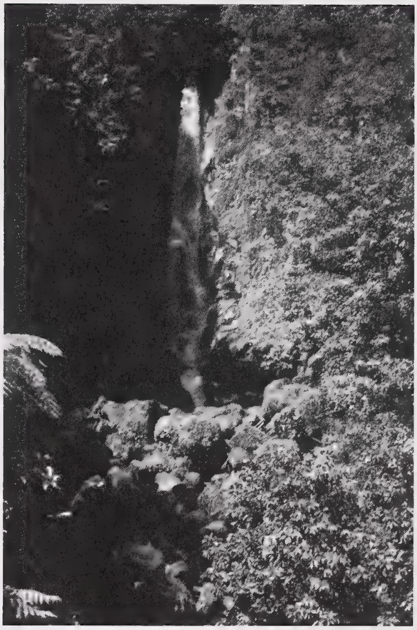
In this section you will learn how cells divide to repair tissues and create growth. You will see the significance of a process called mitosis in maintaining continuity of cells in all organisms. The stages of mitosis, along with methods of cloning cells that are significant to modern medicine, will be covered in some detail. You will complete this section with a look at what happens when mitosis slows down, causing aging, or accelerates, causing cancer.

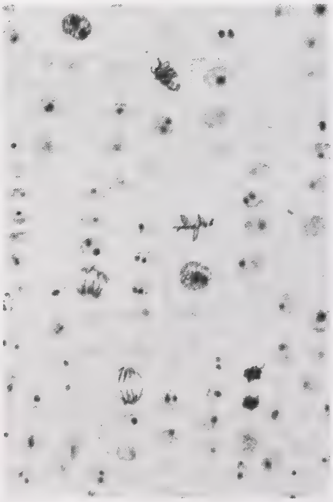
ACTIVITY

1 Cell Cycle and the Principles of Mitosis



Ponce de Leon, a Spanish explorer, spent years looking for the fountain of youth in a part of North America now called Florida. Of course he never found it, but imagine if there was one and you could drink from it! Life would be yours for hundreds of years. No wrinkles until you were at least 500 years old! Alas, what is it that makes human cells last only a little more than one century at best? Why do cells age? Is there a secret to keeping body cells vigorous and young which has not yet been discovered?

Plant Cells in Various Stages of Cell Division



1

You are not the same person you were a year ago. In fact, you are not the same person you were a few seconds ago. Even as you read, your cells are growing, dying, and dividing again and again. New cells replace the old, leading to a complete turnover of many body tissues over a few years. This continuous cell replacement maintains your body and an outward appearance that seems unchanging. Yet your appearance does change over time. Why? The replicate cells that replace worn out and damaged cells should be exact copies of their predecessors, but are they?

To find out whether all cells have the ability to divide and why cell division is so essential, read the section entitled Importance of Cell Division on pages 430 to 431 of your textbook.

---

[1] Courtesy of J. Kuspira and R. Bhambhani, Department of Genetics, University of Alberta.

1. What is the estimated number of cells that make up your body when you reach adulthood? What is the origin of all those cells?

2. a. In what three general ways is cell division important to your body?

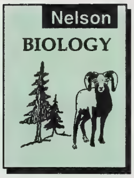
   b. Which of these ways was most important to the individual described in the section introduction after his accident?

Comparing the rate of cell division in skin cells to that of brain and muscle cells shows that not all cells have the same ability to divide.

3. Using your knowledge of cell division, explain the lack of normal sensation and function of the individual's arm four years after the reattachment.

4. Identify several questions about cell division that still remain unanswered.

Check your answers by turning to the Appendix, Section 1: Activity 1.



The first part of the cell theory was proposed by the two German biologists, Mathias Schleiden and Theodore Schwann. Based on their observations they concluded that all plants and animals were made of cells. This has been extended to include all living things. No exceptions have been found. Read the section Principles of Mitosis on pages 431 and 432 of your text for some general information on the process of normal cell division and as an extension of the cell theory in biology.

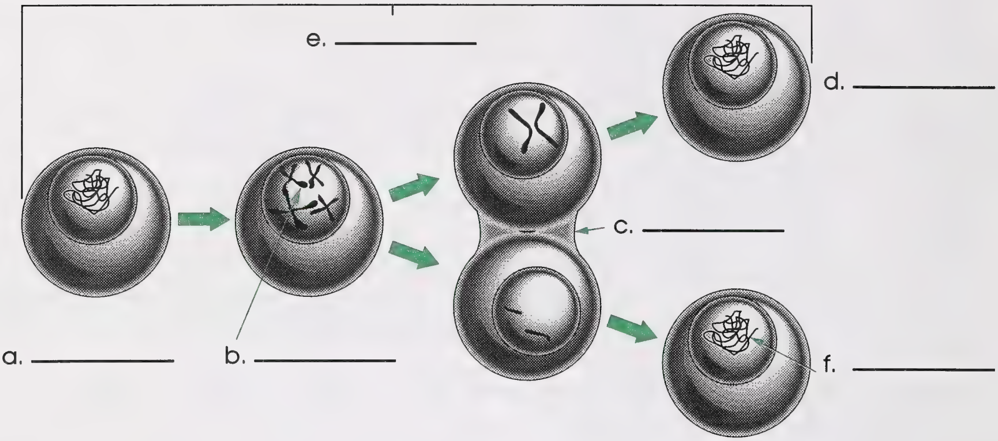
5. What was the second part of the cell theory proposed some forty years later by another German biologist, Rudolph Virchow?

6. In general terms, compare binary fission to mitosis.

It is worth mentioning at this time that the process you are about to study is exactly that – a process. Cell division should be viewed as having a definite beginning and an end. In between times, when a cell is not undergoing cell division, a cell performs normal activities such as respiration, photosynthesis, protein synthesis, absorption, secretion, and excretion. These processes take up most of the cell's life. Perhaps the most important process is the replication of genetic material in the nucleus. This must be completed before a cell divides so that each daughter cell receives the same genetic complement as the parent cell. Once the replication is complete, the cell is ready to divide. During cell division, normal cell activities may be considered to be suspended. This is not exactly the case, as the cell would certainly die, but for your studies here you may accept that a cell's life consists of periods of normal cell activities interspersed by periods of cell division.

Cell division begins with the division of the nuclear material followed by the division of the cytoplasm and organelles. Depending on the kind of organism and tissue, this process may occur in minutes, hours, or even years. Before you look at this process in detail, you should become familiar with some basic terminology.

7. Label the terms on the following diagram: *mother cell, daughter cells, chromosomes, mitosis, division of cytoplasm,* and *chromatin.*



8. A skin cell taken from a chimpanzee contains forty-eight chromosomes.

   a. How many chromosomes would there be in the nerve or bone cells of this animal?

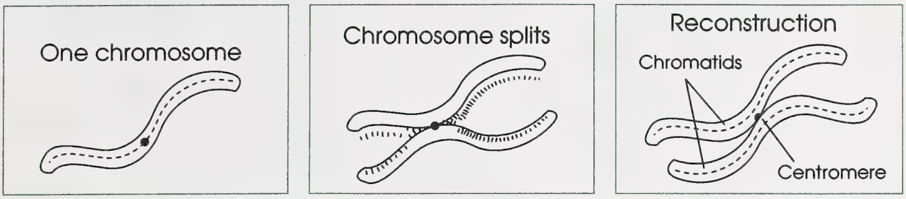
   b. If a skin cell of the chimpanzee underwent cell division, how many chromosomes would there be in each daughter cell?

Check your answers by turning to the Appendix, Section 1: Activity 1.

The essence of a cell, all of what it is and what it does, is determined by the genetic code in the genes making up chromosomes. A cell cannot function normally without a complete set of this information. It would be similar to missing a portion of your brain. So before a cell can divide into two cells, it must replicate its chromosomes so that each new cell has the necessary instructions to make it work. If there are seventy-eight chromosomes, as in a dog's cell, then all seventy-eight chromosomes must be reproduced so that a set of seventy-eight go to one daughter cell and another set of seventy-eight go to the other.

The process of making identical copies of chromosomes prior to division is called replication.

In simplified terms, chromosome replication can be summarized as shown.



Once the chromosomes have been completely replicated, the cell is ready to divide. A detailed account of cell division is given on pages 432 to 435 of your text. Read this section very carefully before proceeding.

9. Differentiate between chromosome, chromatid, and chromatin.

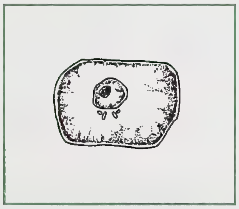
Centrioles are generally missing in plant cells, which indicates they are not essential for mitosis in plants.

10. What role do centrioles play in cell division of animal cells?

11. The stages of cell division are arbitrarily divided into five phases with four of these making up stages in which the cell is actively dividing. List these in the order in which they occur.

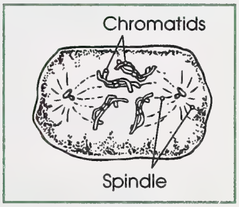
The other phase, interphase, is a period to time when a cell is not dividing. This is the phase in which a cell spends most of its life. You must be able to recognize these phases and describe the main events that occur in each of them. Study the photographs of mitosis in Figure 18.5 on page 433 and the sketches in Figure 18.6 on pages 434 to 435 of your text. Compare the schematic drawings of each phase to the photographs to get a sense of perspective of what is happening and what it really looks like under the microscope.

Stages of Mitosis



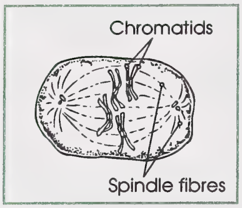
A. Interphase

- Chromosomes replicate.
- Normal cell activities occur.



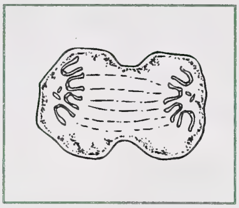
B. Prophase

- Chromosomes shorten and thicken.
- Chromatids (duplicated chromosomes) are connected to fibres on opposite ends of poles to form a spindle.



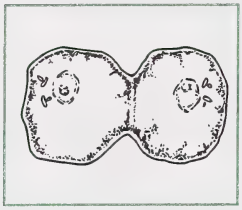
C. Metaphase

- Chromosomes align along the equator of the cell.



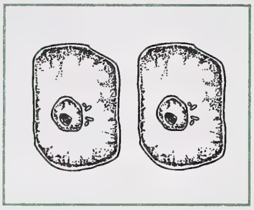
D. Anaphase

- Chromatids separate and move to opposite poles.



E. Telophase

- Nuclear membrane and nucleoli form.
- The spindle dissolves.
- Chromosomes become longer and thinner.
- Cytoplasm divides.



F. Interphase

- Two daughter cells contain the same genetic information as the parent cell.
- Cells return to interphase.

12. Match the events given in each statement with the correct stage of mitosis shown in the diagram.

A. Interphase B. Prophase C. Metaphase D. Anaphase E. Telophase

Diagram **Event**

_______ a. Normal growth and functioning of the cell occurs here.

_______ b. Chromosomes replicate to produce two sets of chromosomes in preparation of cell division.

_______ c. Chromosomes with their duplicates still attached shorten by coiling, thus becoming visible under the microscope.

_______ d. Centrioles migrate to opposite sides of the cell and the nuclear membrane dissolves.

_______ e. Spindle fibres grow from each centriole and attach to the centromere of each chromatid pair.

_______ f. Chromatid pairs still joined at the centromere line up along the middle of the cell called the metaphase plate.

_______ g. Chromatids are pulled apart by shortening of the spindle fibres. One complete set of chromosomes is pulled to each pole.

_______ h. Chromosomes uncoil, spindle fibres dissolve, and cytoplasm divides. Two daughter cells are formed.

Mitosis is immediately followed by division of the cytoplasm leading to the formation of two independent daughter cells.

13. Name the process of cytoplasmic division and describe how it is different in plant and animal cells.

Check your answers by turning to the Appendix, Section 1: Activity 1.

PATHWAYS

If you have access to supervised laboratory facilities, do Part A.
If you do not have access to laboratory facilities, do Part B.

Investigation: Mitosis

Part A

Objective

The objective of this investigation is to identify cells in interphase and the four stages of mitosis and to calculate the rate of cell growth.

Materials

- microscope
- unlined paper
- graph paper
- lens paper
- ruler
- prepared slides of onion root tip
- prepared slides of whitefish blastula
- pencil

Procedure

- Follow the instructions for this activity as given on page 436 of your text.
- Be sure to answer all the questions as you progress through the activity.

Science Skills

☐ A. Initiating
☑ B. Collecting
☑ C. Organizing
☑ D. Analysing
☐ E. Synthesizing
☐ F. Evaluating

14. Make a sketch of one cell in each of the phases of mitosis. Label all visible structures that you can identify. Include a title to identify each stage of mitosis. All labels should be neatly written; a ruler should be used to draw a line connecting the label to the correct structure.

    The structures visible in each phase would include the following:

    a. interphase – nuclear membrane, chromatin, cytoplasm, nucleolus, cell wall

    b. early prophase – chromosomes or chromatids, cytoplasm, nuclear membrane, cell wall

    c. late prophase – chromatids, cytoplasm, cell wall

    d. metaphase – chromatids, spindle fibres, cytoplasm, and cell wall
    The metaphase or equatorial plate is an imaginary line along which the chromatids line up.

    e. anaphase – same structures as in metaphase

    f. late telophase – chromatin, possibly a nuclear membrane, nucleolus, cell plate, and cell wall

Observations

Use the following table to answer question 15.

Phase	Area 1	Area 2	Area 3	Total Number of Cells in Each Phase	Time in Minutes
Interphase	95	75	84		
Prophase	13	12	21		
Metaphase	5	4	5		
Anaphase	1	0	2		
Telophase	3	2	4		
			Total Number		

15. a. Complete the table by adding the total number of cells in each phase.

    b. Calculate the time required for each phase of mitosis in onion skin cells from the information given in the table. Record these figures in the last column of the table. Use the total of the three areas counted and assume the total time taken is 720 min. Use the following procedure.

Time spent in a mitotic phase and in interphase can be calculated if the total time for mitosis is known. Onion cells require 720 min (12 h) to complete mitosis from interphase to interphase. The amount of time needed for a phase can be calculated using the formula:

$$\text{time for a phase} = \frac{\text{number of cells in a phase}}{\text{total number of cells counted}} \times 720 \text{ min}$$

For example, if 98 cells were counted in metaphase and 980 cells in total were counted, then $\frac{98}{980} \times 720 \text{ min} = 72 \text{ min}$.

Interpretation and Analysis

16. Complete Procedure questions a, c, d, e, f, g, and h from page 436 of your text.

17. Complete Application questions 1 to 4 found on page 436.

Use the data from the observation table to answer the next series of questions.

18. a. Draw a bar graph of the time taken by each phase of mitosis.

    b. Which phase of the cell cycle requires the longest time to complete?

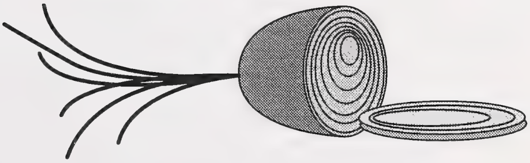
    c. Which is the shortest phase?

Check your answers by turning to the Appendix, Section 1: Activity 1.

Part B

Objective

The objective of the investigation is to identify the phases of mitosis and to label the structures visible in microslides of an onion root tip.



Materials

- microslide set 55, Plant Mitosis
- graph paper*
- pencil*
- microslide viewer
- unlined paper*

*supplied by student

Procedure

- The phase of mitosis for each microslide is identified. Compare each phase in the microslides with the appropriate pictures in this section and also with those on page 433 of your text to identify visible components and to get a sense of what is really happening.

- Read the background information on each phase provided on the microslide folder.

19. Sketch a cell in each phase of mitosis including interphase and label only the structures that you can see. The visible structures in each phase would include the following:

    a. interphase – nuclear membrane, chromatin, cytoplasm, nucleolus, cell wall

    b. early prophase – chromosomes or chromatids, cytoplasm, nuclear membrane, cell wall

    c. late prophase – chromatids, cytoplasm, cell wall

    d. metaphase – chromatids, spindle fibres, cytoplasm, cell wall
    The metaphase or equatorial plate is an imaginary line along which the chromatids line up.

    e. anaphase – same structures as in metaphase

    f. late telophase – chromatin, possibly a nuclear membrane, nucleolus, cell plate, cell wall

- Place the microslide set back in the folder.

20. Do question 15 in Part A.

Analysis and Interpretation

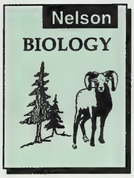
21. Name one reason why mitosis must be so organized and precise.

22. What crucial event, which is invisible under the light microscope, occurs towards the end of interphase before a cell can undergo mitosis?

23. Normally chromosomes are extremely long invisible strands. Explain why they become visible structures under normal magnification of a light microscope during mitosis.

24. The daughter cells of a mitotic division each have twenty chromosomes. What must have been the number of chromosomes in the original mother cell before chromosome replication leading up to mitosis?

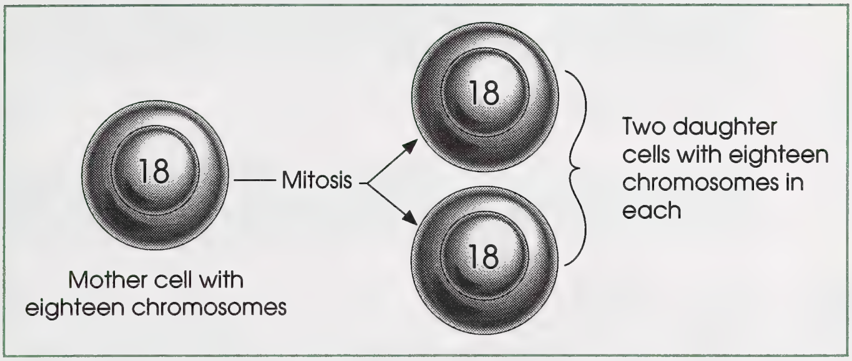
25. What phase of the cell cycle do the daughter cells go into once they are formed?



26. Do Procedure question d from page 436 of your text, using onion cells seen in your slide set rather than whitefish cells.

Check your answers by turning to the Appendix, Section 1: Activity 1.

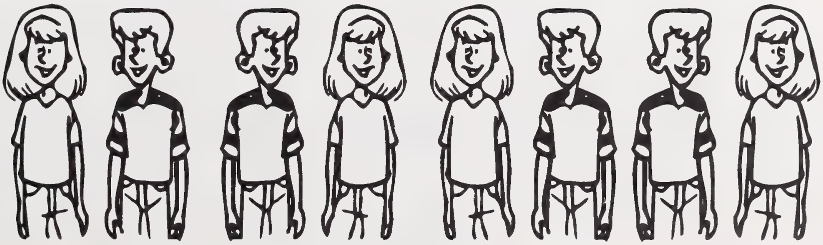
In summary, the process of mitosis produces two cells that are genetically identical to the original mother cell. The schematic diagram represents the end result of mitosis.


18
Mitosis
18
18
Two daughter cells with eighteen chromosomes in each
Mother cell with eighteen chromosomes

ACTIVITY

2 Cloning and Regeneration

When you look in a mirror you are looking at a human being that is one of a kind. Unless you happen to be an identical twin, not one of the billions of people on this planet would be exactly like you. Imagine travelling to another world where you discover that the men all look exactly alike and so do the women. You begin to question your eyesight. How can this be? Even more fascinating is that they all appear to be the same age. What has really happened on this planet?



In nature, genetically identical individuals are common. To understand how this happens, read the section entitled Cloning on pages 437 to 439 of your text.

1. Define the term *cloning* and give an example of natural cloning in the plant and the animal worlds.

2. a. In what novel way did Fredrick Stewart make use of cloning?

   b. How was this research economically important?

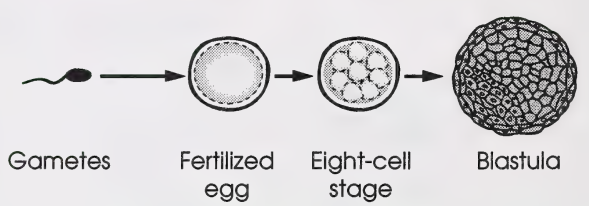
3. Complete the table to summarize the general details of cloning.

Plants Cloned Commercially	**Plants That Cannot Be Cloned**	**Advantages of Cloning**	**Kind of Cells Needed for Cloning**

Check your answers by turning to the Appendix, Section 1: Activity 2.

In animals, a fertilized egg cell undergoes rapid mitotic division forming a ball of cells called a blastula. Cells taken at the blastula stage can be used for cloning some animals such as frogs. For mammals, such as mice, these cells are already too specialized. Mammal cells may have to be harvested at the eight-cell stage or earlier for successful cloning.

Mitosis to the Blastula Stage



4. What cells can be used to clone mice?

5. What do biologists mean by the word *totipotent*?

6. Suggest two medical applications of cloning for humans that may be possible in the future.

7. What major problem associated with transplanting organs and tissues would be overcome with the use of cloning? Explain why.

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BIOLOGY

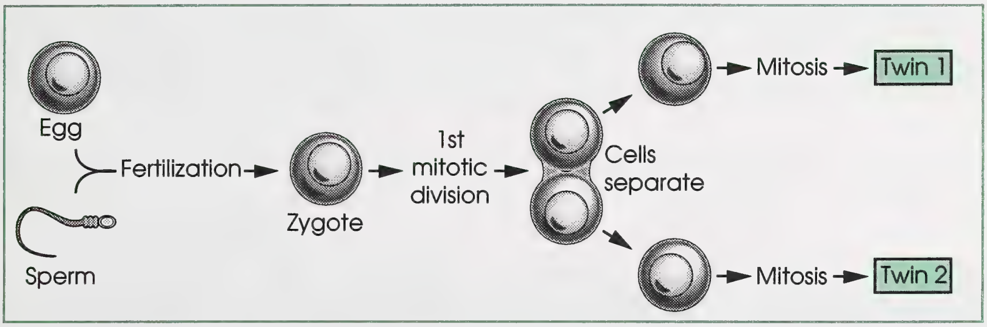
Read the sections entitled Frontiers of Technology: Liver Tissue Transplants and Identical Twins: Nature's Clones on page 439 and 440 of your text.

8. Only fragments of Mrs. Smith's liver tissue were transplanted to her daughter, Alyssa. Explain why this procedure of transplant will work with liver tissue, whereas with heart and kidney transplants the entire organs must be used.

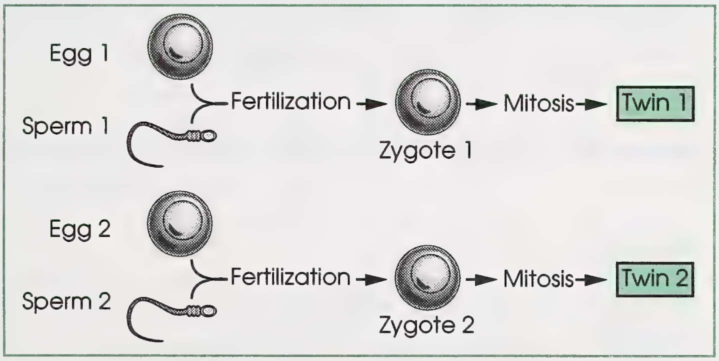
Natural clones in humans are called identical twins. Twins result in one of two ways. The two flowcharts that follow show each process.

9. Label the twins at the end of each process as identical or fraternal.

   a. Process X



   b. Process Y



10. Explain why identical twins are clones but fraternal twins are not.

Triplets and higher-multiple births could technically occur the same way as either kinds of twins. However, complete division into two identical unspecialized cells becomes less likely after the initial mitotic divisions. As you have seen, the cells soon begin to specialize. Consequently, multiple births beyond twins is more likely the result of multiple ovulation and all offspring will be fraternal.

Read the section of your text entitled Cell Death and the Aging Process on pages 440 to 442. It will give you some insight into why cells age.

11. "Cell division appears to be regulated by a biological clock." Explain this statement making reference to research done with immature heart cells.

Cells of complex organisms like you go through an aging process. Among simple bacteria aging does not exist. When a bacterial cell reaches a certain size, it divides into two cells by fission and then continues to repeat the process. Subsequent generations of bacteria are as viable as the first.

12. Only two types of cells in the human body escape aging. Which ones are they?

Cells need time to specialize. It also appears that the more specialized a cell is, the less it is able to undergo mitosis.

13. How is specialization affected in cancerous cells? Explain.

14. The basic question of what causes aging has not been answered yet, but three hypotheses have been proposed. Summarize each of them and indicate whether there is any evidence to support any one of them.

Check your answers by turning to the Appendix, Section 1: Activity 2.

Cell division normally is under the control of the cell. It is also clear that normal cells cannot divide in isolation of one another – cell-to-cell communication is essential. What then happens in some cells that changes these parameters and leads to abnormal cell division and cancerous tissue?

In the next activity you will learn about some surprising changes that can occur in cells.

ACTIVITY 3

Cancer in Cells

Read the section entitled Abnormal Cell Division: Cancer on pages 442 to 443 of your text for more information on cell division out of control.

1. Give a general definition for the term *cancer*.

2. Compare the properties of normal and cancerous cells in humans by filling in the table.

Type of Cell	Rate of Reproduction	Ability to Reproduce in Isolation (yes/no)	Ability to Differentiate (yes/no)	Adhere to Other Cells (yes/no)
Normal Cell				
Cancerous Cell				

3. What is metastasis and why is it so dangerous?

Check your answers by turning to the Appendix, Section 1: Activity 3.

Investigation: Identification of a Cancer Cell

PATHWAYS

If you have access to supervised laboratory facilities, do Part A.
If you do not have access to laboratory facilities, do Part B.

Part A

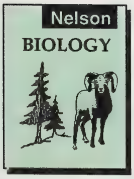
Objective

The objective is to identify cancerous cells and to recognize the difference between cancerous and noncancerous cells.

Materials

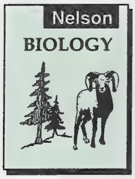
- light microscope
- ruler
- lens paper
- prepared slide of squamous cell carcinoma
- unlined paper
- pencil

Procedure



- Complete the investigation as described on page 444 of your text.
- Answer all questions as you go through the activity.

Observations



Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

4. Do Procedure question a found on page 444. Your line diagram should be relatively large.

Analysis and Interpretation

5. Do Procedure questions b to g and the Laboratory Application Questions.

Mitosis does not occur at the same rate in all organisms and it changes for cells that have become cancerous.

Answer the next series of questions using the following table.

Time for Mitosis of Normal and Cancerous Chicken Stomach Cells		
Phase	**Normal Chicken Stomach Cells (Minutes)**	**Cancerous Chicken Stomach Cells (Minutes)**
Interphase	540	380
Prophase	60	45
Metaphase	10	10
Anaphase	3	3
Telophase	12	10

6. a. What is the total time needed for a normal chicken stomach cell to complete mitosis?

   b. What is the total time needed for a cancerous chicken stomach cell to complete mitosis?

   c. How do cancer cells differ from normal cells in time spent for each phase? Describe the relative time for mitosis of cancerous cells.

Check your answers by turning to the Appendix, Section 1: Activity 3.

Part B

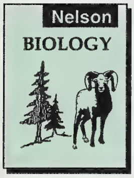
Objective

The objective of this investigation is to compare the chromosome composition of a cancerous cell to a normal cell.

Materials

- photograph of normal human karyotype
- photograph of a human cancerous cell karyotype

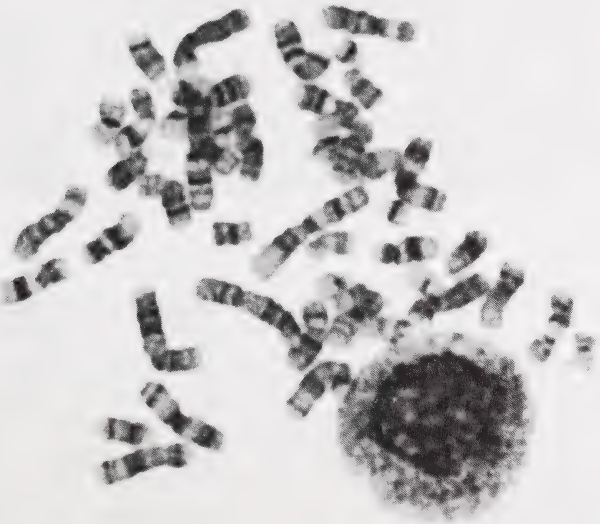
Background Information



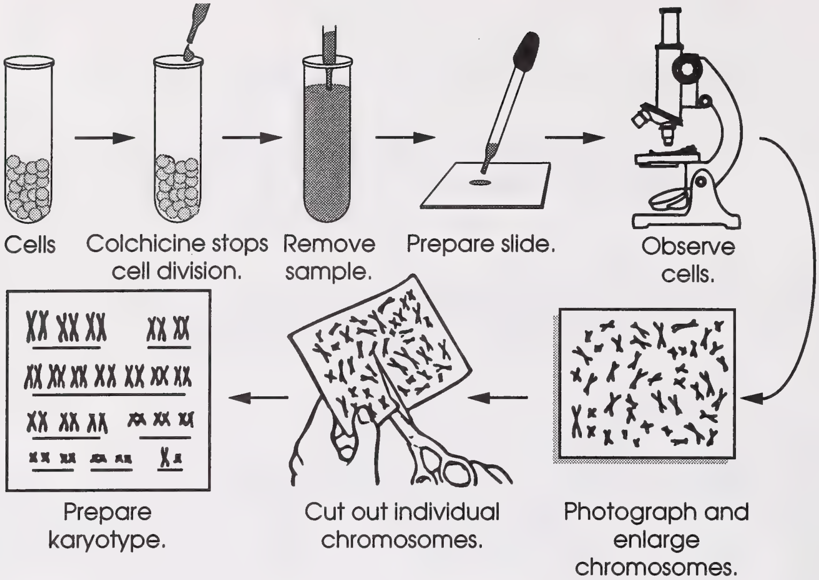
A karyotype is made by photographing the chromosomes of a cell in metaphase. The chromosomes will be thicker and shorter than in other phases. Metaphase may be stopped using a drug such as colchicine. The cell may be plasmolysed with an hypotonic solution to release the chromosomes. The following photograph shows the chromosomes from a cell in metaphase. The dark round object is another cell still in interphase. To make the karyotype, the chromosomes will be cut out and arranged in pairs on a chart. Normal human karyotypes show twenty-two autosomal pairs and one pair of sex chromosomes. The chromosomes are numbered from one to twenty-two. See pages 455 and 459 of your text for additional details about karyotypes.

plasmolysed – as in plasmolysis, a process in which a cell absorbs water, swells, and bursts

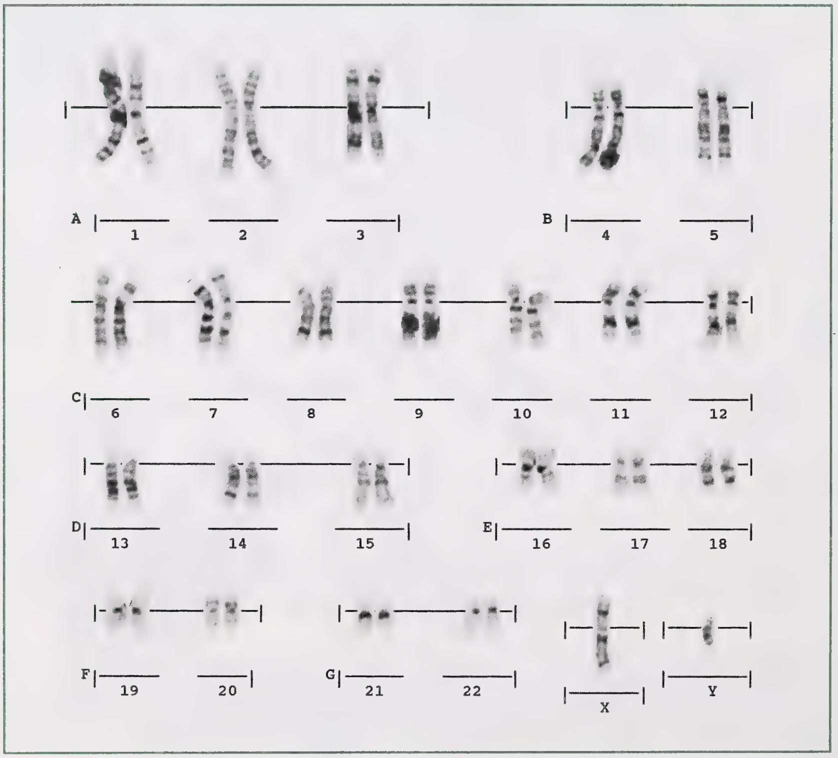
hypotonic – lower concentration of solute; opposite to hypertonic



COURTESY OF CROSS CANCER INSTITUTE, EDMONTON, ALBERTA, CANADA


Cells
Colchicine stops cell division.
Remove sample.
Prepare slide.
Observe cells.
Photograph and enlarge chromosomes.
Cut out individual chromosomes.
Prepare karyotype.

Normal Cell Karyotype



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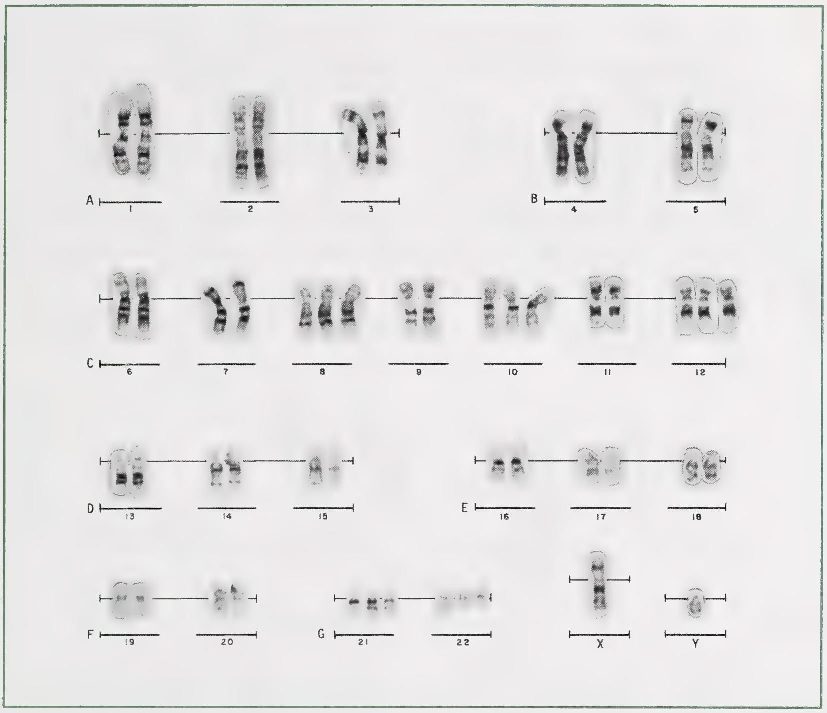
Cancerous Cell Karyotype



COURTESY OF J. KALETA, R.T., CYTOGENETICS

Procedure

- Carefully study the karyotype of a normal human cell and a cancerous cell. Notice that chromosomes come in pairs with each member of a pair being identical in size and shape. All the pairs are numbered for easy reference.

Observations

Science Skills

☐ A. Initiating
☑ B. Collecting
☑ C. Organizing
☑ D. Analysing
☐ E. Synthesizing
☐ F. Evaluating

7. Count up all the chromosomes and record the number for each karyotype.

8. Compare the chromosomes of the cancerous cell to those of the normal cell. Where does the chromosome count differ? Identify and describe any differences in chromosome numbers found by comparing the karyotypes.

Knowing precisely where changes in chromosome numbers as well as other changes occur is very helpful in identifying types of cancer. Look carefully at chromosome 22 in the cancer cell.

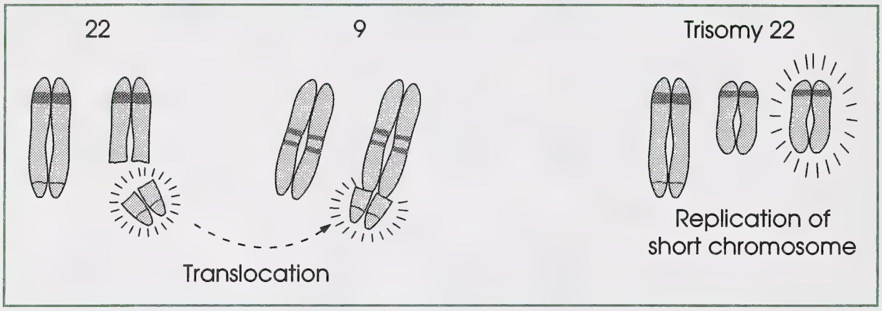
9. Compare the chromosomes in this trisomy to the normal karyotype.

A medical technologist trained in examining karyotypes would be able to see that a part of chromosome 22 is missing. Look closely at chromosome 9 in the cancerous karyotype.

10. Are the chromosomes identical? Describe any difference.

translocates – a segment of a chromosome moves from one chromosome to another

One of the chromosomes has gained some material. In this type of cancer, a small part of chromosome 22 translocates to chromosome 9. Then the shortened chromosome 22 replicates creating trisomy.



Translocation and trisomy is diagnostic for many cancers.

Check your answers by turning to the Appendix, Section 1: Activity 3.

Not all types of cancer cells will have abnormal karyotypes. In general, cancer cells produced by radiation and chemicals will show such chromosome abnormalities. It still is not certain whether the abnormal chromosome composition precedes the cancer, eventually giving rise to the cancerous nature of the cell, or whether it is one of the changes produced by the cancer itself.

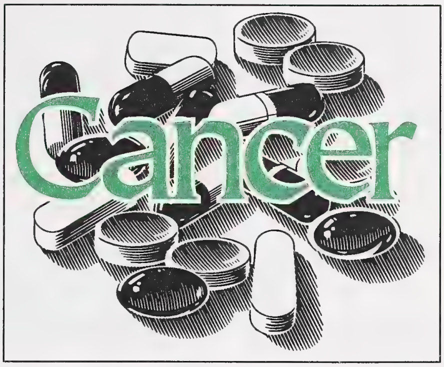
The rate at which cells will cycle through cell division and normal activity is influenced by a number of factors including chemicals. For example, when actively dividing cells are exposed to colchicine, they will not complete division. The chemical arrests mitosis in metaphase by inhibiting the shortening of the spindle fibres.

Read the following Case Study and answer the next questions.

Case Study: Chemotherapy

Knowing that certain chemicals interfere with the process of mitosis, researchers set out to find drugs that would help in curing cancer. This has led to a cancer treatment method called chemotherapy, or treatment by drugs. Since cancer cells continually and rapidly divide, any chemical which blocks cell division or kills cells when they are dividing will have a much greater effect on cancerous cells than on normal ones. However, these drugs will also destroy other fast-growing cells in the body, such as hair follicles. This explains the loss of hair by patients on chemotherapy.

There are now more than two dozen different anticancer drugs which can be used to treat cancer. One drug used in chemotherapy is methotrexate. Methotrexate attaches to certain enzymes involved in chromosome (DNA) replication and prevents them from functioning. Without these enzymes, new molecules of DNA cannot be synthesized. If cell division does not take place among these drug-damaged cells, none of the newly formed cells will survive. Methotrexate is generally quite successful at first, but like other similar drugs, it loses its effectiveness over time. Studies show that the cancer cells become resistant to these anticancer drugs. Researchers believe that resistance to methotrexate occurs because the drug-treated cancer cells produce multiple copies of the specific gene that is affected by the drug. Methotrexate alters the DNA molecules in cancer cells so that some genes begin to multiply uncontrollably. One of these genes directs the synthesis of the DNA-replicating enzyme, the exact enzyme that the drug inhibits. Multiple copies of this gene causes a pronounced increase in the production of the DNA-replicating enzyme, which in turn causes a dramatic increase in the rate of DNA replication within the cancer cells. This leads to an increase in the rate of cell division. Daughter cells from these altered cells also show multiple genes and a more rapid rate of cell division. Ironically, the very drug that stops cancer cells from dividing also has the effect of making these cells more resistant. Eventually, the chemical's inhibition of cell division in cancer cells is not effective enough to be useful.



Two other drugs used in the treatment of certain cancers are vinblastine and vincristine. These two drugs have been discovered in the Madagascar periwinkle, *Catharanthus roseus*. Vincristine is very effective in the treatment of leukemia and vinblastine in the treatment of Hodgkin's disease. Vinblastine doubles the chance of surviving Hodgkin's disease. Currently the only practical source of the two drugs is from the plant. However, to produce 5.0 g of vincristine an expensive and laborious process requiring 1000 kg of periwinkle stems is used. Chemists have successfully synthesized the substances, but this is even more expensive. At present, new methods of culturing the plants are being developed to speed up the production of these drugs. The medical potential of Madagascar periwinkle is a good example of why conserving plant diversity is so important.

11. Compose a very short description of chemotherapy and how it controls cancer cells.
12. Explain why patients lose their hair when on chemotherapy.
13. What effect does the drug methotrexate initially have on cancerous cells that makes it an effective drug in cancer treatment?
14. Why does the drug methotrexate lose its effectiveness over time?
15. Why is there such concern about the loss of plant species around the world and how is this connected with cancer treatment?

Check your answers by turning to the Appendix, Section 1: Activity 3.

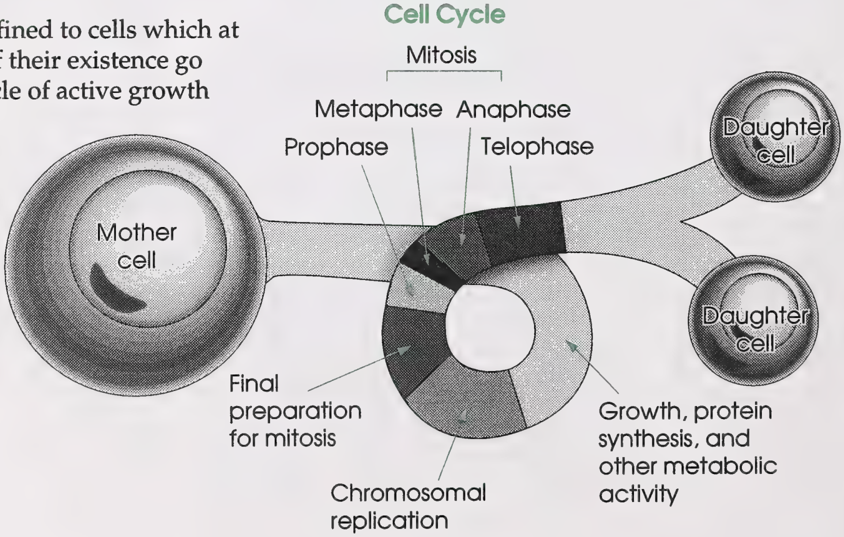
Mitotic division must be a precise process to produce cells with the same genetic instructions as their predecessors. A great deal of cellular energy and effort is spent on the actual replication of the chromosomal material. Dividing up the two sets of chromosomes is what you have looked at in some detail in this section. The chemistry of chromosomal replication will be covered in Module 5.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

All life is confined to cells which at some point of their existence go through a cycle of active growth and division.



When cells reach a certain size they undergo mitotic division which results in two daughter cells genetically identical to the original mother cell. In this way, unicellular organisms can increase in numbers while multicellular organisms can add new cells for growth or repair of worn out or damaged cells. Mitosis is arbitrarily divided into phases with crucial events occurring in each. Chromosomal replication occurs in the latter stages of interphase so that one complete set of chromosomes is available for each new daughter cell. The separation of these two sets must be precise and it takes up the rest of the mitotic process. Cell division is under the control of the cell and is influenced by other adjacent cells. The more specialized a cell, the less ability it has to divide. Sometimes cells lose control of their rate of mitosis and proliferate at a rapid rate forming cancerous cells. A form of reproduction in which new individuals are generated from body cells rather than egg and sperm is called cloning.

The following questions are intended to assist you in developing a better understanding of the concepts covered in this section.

1. Match the definition with the correct term.

- mitosis
- cloning
- mother cell
- totipotent
- centromere
- chromosome
- differentiation
- identical twins
- cytokinesis
- regeneration
- binary fission
- spindle fibres

__________ a. division of the cytoplasm

__________ b. replacement of a part of the body that has been damaged or lost

__________ c. division of nuclear material, more generally refers to normal cell division

__________ d. a cell that undergoes mitosis and cytokinesis

__________ e. the ability to develop from an egg to an adult

__________ f. a simple form of reproduction in a single-celled organism which involves only mitosis

__________ g. a long strand of genetic material

__________ h. production of identical individuals from the body cells of an organism

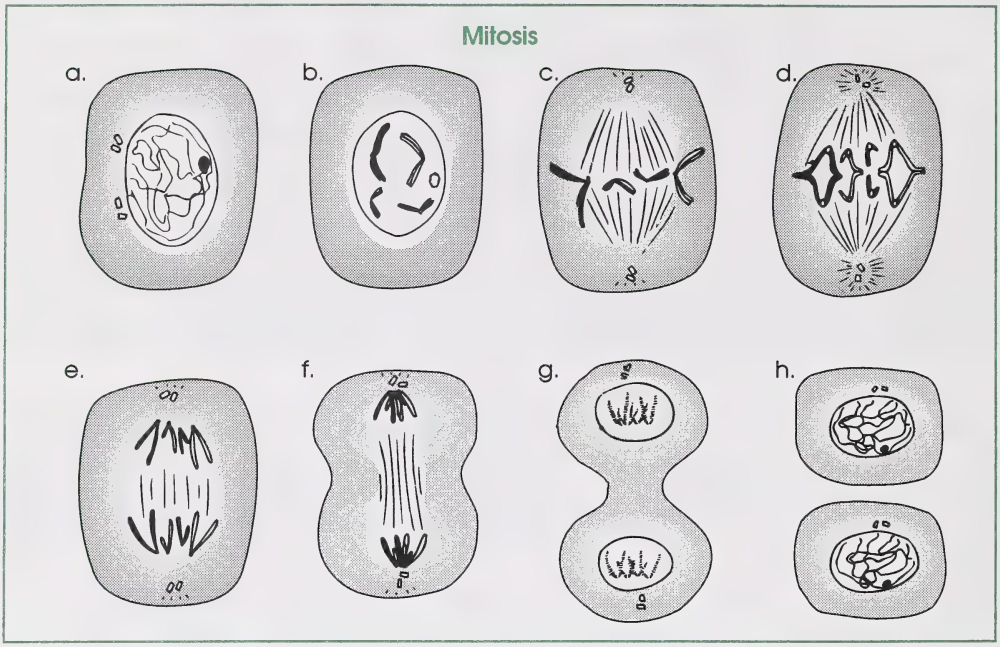
__________ i. point of attachment of chromatids

__________ j. process by which cells specialize to perform a specific function

__________ k. human clones produced naturally from cells originating from one fertilized egg

__________ l. protein filaments that shorten and pull chromatids apart during anaphase of mitosis

2. Identify the phase of mitosis for each cell.



3. Match the following events with the correct phase of mitosis seen in the previous question.

_______ a. Chromosomes coil up and become indistinct under the microscope.

_______ b. Chromatids are separated by shortening of the spindle fibres.

_______ c. Cytokinesis occurs.

_______ d. Normal cellular activity occurs here.

_______ e. Chromatid pairs line up on the metaphase plate.

_______ f. Chromosomes uncoil.

_______ g. Asters are first most prominent.

_______ h. Daughter cells are being formed.

4. Draw a concept map that shows the connections between the following terms: *normal mitosis, uncontrolled mitosis, cancer, specialization, no specialization, metastasis, tumour,* and *death.*

Check your answers by turning to the Appendix, Section 1: Extra Help.

Enrichment

Use the table to answer the following questions. The table shows the length of time in minutes needed for mitosis to occur in two different normal organisms.

Time Needed for Mitosis (minutes)					
	Prophase	**Metaphase**	**Anaphase**	**Telophase**	**Total**
Salamander Kidney Cells	60	50	6	70	186
Pea Root Cells	80	40	4	12	136

1. a. Which phase shows the most significant time difference for the two organisms?

   b. Which organism shows time needed to complete mitosis similar to the data you saw in the table in the investigation on mitosis. Suggest one reason why they would be similar.

   c. Which structure, the kidney or the root, could undergo more rapid growth? Explain.

   d. Can you conclude from these results that plants in general take less time to complete mitosis than do animal cells? Explain.

2. Under ideal conditions a bacterium will divide once every 20 min.

   a. Calculate the time a bacterium spends in each phase of mitosis if the total time between divisions is 20 min and the proportion of time in each phase is as follows:

   prophase = 64% metaphase = 20% anaphase = 4% telophase = 12%

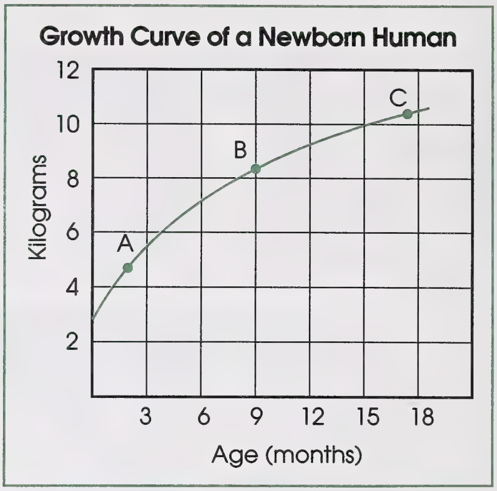
   b. Calculate the number of bacteria cells you would have on a culture plate after 24 h if you started with one bacterium and division occurred regularly once every 20 min. Assume none of the bacteria die and the first division took place 20 min after you got the plate.

3. Read about oncogenes on pages 544 to 546 in your text to find out what they are and how they are connected to malignant (cancerous) tissue. Briefly describe how oncogenes may cause cancer.

4. In terms of the rate of mitosis, explain the general trend in growth of the human infant shown in the graph on the right. Describe the relationship between cell division and cell loss at points A, B, and C.

5. Write to the Canadian Cancer Society for information on the connection between cancer and genetics.

Canadian Cancer Society
#200 2424 – 4th St. S.W.
Calgary, Alberta
T2S 2T4



Check your answers by turning to the Appendix, Section 1: Enrichment.

Conclusion

Organism size ranges from microscopic bacteria to the blue whale, the largest animal to ever inhabit the Earth. The difference in these organisms is not the size of their cells but the number of their cells. Bacteria consist of one cell; the whale of trillions of cells. Yet, in both cases, cell division is crucial. When a bacterial cell undergoes mitosis, it reproduces, generating clones of itself in the process. When cells of a whale undergo mitosis, growth may occur or repair or replacement of worn-out cells may occur.

Although mistakes are occasionally made, mitosis is a precise process producing two cells genetically identical to the original cell. In this way, nature has cloned new cells ensuring a continuity of life from generation to generation since life's first appearance on this planet. The rate of cell division varies from cell to cell even in the same organism and it changes over time. If this control of mitosis is lost, rapid growth of unspecialized cells leads to cancer and inevitable death.

The next time you cut or scrape yourself, be thankful for mitosis.

30

Section 1 Assignment: Asexual Cell Reproduction

Response Page Setup

Review the Evaluation information found in the introductory pages of this module.

It is important to number and clearly identify each page with the following information at the top:

Biology 30 – Module 4 Section 1 Assignment Page # Name and ID#

Be sure to write legibly. Leave a wide left margin and number all of your pages.

Carefully read each of the following multiple choice questions and decide which of the choices **best** completes the statement or answers the question. Each question is worth 1 mark.

1. If the normal chromosome number of corn is twenty, what would be the chromosome number of each cell after mitosis?

   A. 10
   B. 20
   C. 30
   D. 40

2. In mitosis, cleavage of mother cells into daughter cells occurs

   A. immediately after prophase
   B. during telophase
   C. at metaphase
   D. during anaphase

3. Which of the following statements is part of the cell theory?

   A. All organisms consist of many cells.
   B. Cells may be produced by spontaneous generation.
   C. All cells come from pre-existing cells.
   D. A cell is the species for all living organisms.

4. In any one animal the chromosome number is exactly the same in

   A. the body cell and the unfertilized egg
   B. the zygote and the sperm
   C. the unfertilized egg and the zygote
   D. the body cell and the zygote

5. Which of the following is the correct sequence of mitosis?

   A. telophase, anaphase, metaphase, prophase
   B. anaphase, telophase, prophase, metaphase
   C. prophase, anaphase, metaphase, telophase
   D. prophase, metaphase, anaphase, telophase

6. Of the following, which is a function of the mitotic process?

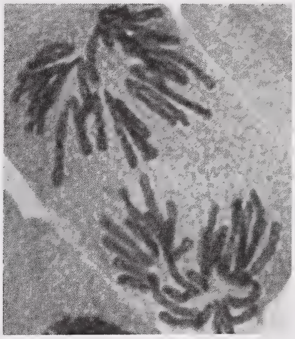
   A. repair of injured sperm-producing tissue
   B. development of male or female gametes
   C. reduction of the parental chromosomal number
   D. preparation for recombination of genetic material

7. Certain cells have twice as much DNA as other normal cells of the same organism. This is true of

   A. cells that show a decrease in activity of the ribosomes
   B. cells that are in an early stage of mitosis
   C. a newly formed sperm cell
   D. an egg cell immediately before fertilization

8. The diagram illustrates a cell in

   A. interphase
   B. anaphase
   C. telophase
   D. metaphase


[1]

9. One characteristic of cancerous cells that makes them different from normal cells is that they

   A. have a long cell cycle
   B. go through rapid cell division
   C. have a short life span
   D. are very sticky

10. Cell division in plant cells is different from that of animal cells in that plant cells

    A. separate the cytoplasm with a cell plate
    B. do not divide the nuclear material
    C. rarely perform mitosis
    D. have centrioles to which chromosomes are pulled during mitosis

11. Determine the stage in cell division where the following events occur.

    a. Cytokinesis is occuring. ______________ **(1 mark)**

    b. Cell growth and normal biochemical activity is occuring. ______________ **(1 mark)**

    c. Substantial shortening of spindle fibres occurs. ______________ **(1 mark)**

---

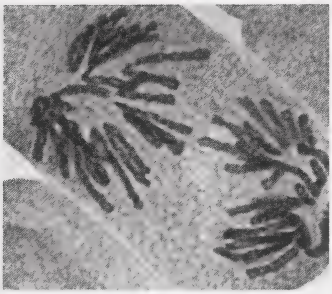
[1] Courtesy of J. Kuspira and R. Bhambhani, Department of Genetics, University of Alberta.

d. Chromatids position across the cell prior to separation. ____________ **(1 mark)**

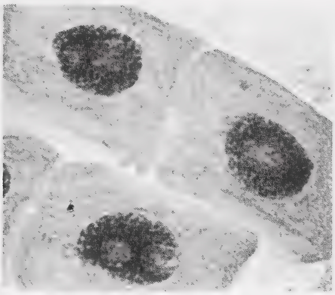
e. Chromosome replication occurs producing identical chromatids. ____________ **(1 mark)**

12. Determine the correct order of these photographs of the cell cycle.[1] Write the letters in correct order and identify each phase. **(5 marks)**

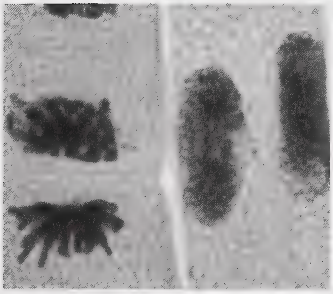
a.



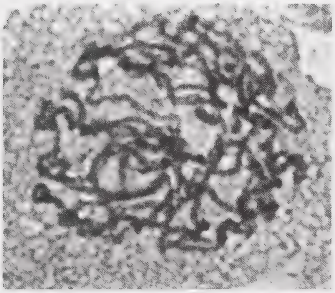
b.



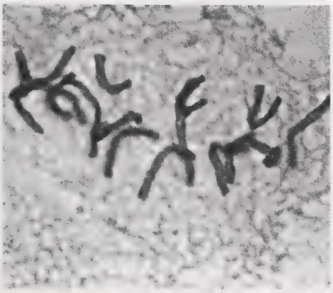
c.



d.



e.



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[1] Photographs courtesy of J. Kuspira and R. Bhambhani, Department of Genetics, University of Alberta.

13. Explain why fraternal twins are no more similar than two siblings born at different times. **(2 marks)**

14. In a paragraph present four ways that cancer cells differ from normal cells. **(4 marks)**

Science Skills

☐ A. Initiating
☐ B. Collecting
☐ C. Organizing
☑ D. Analysing
☐ E. Synthesizing
☐ F. Evaluating

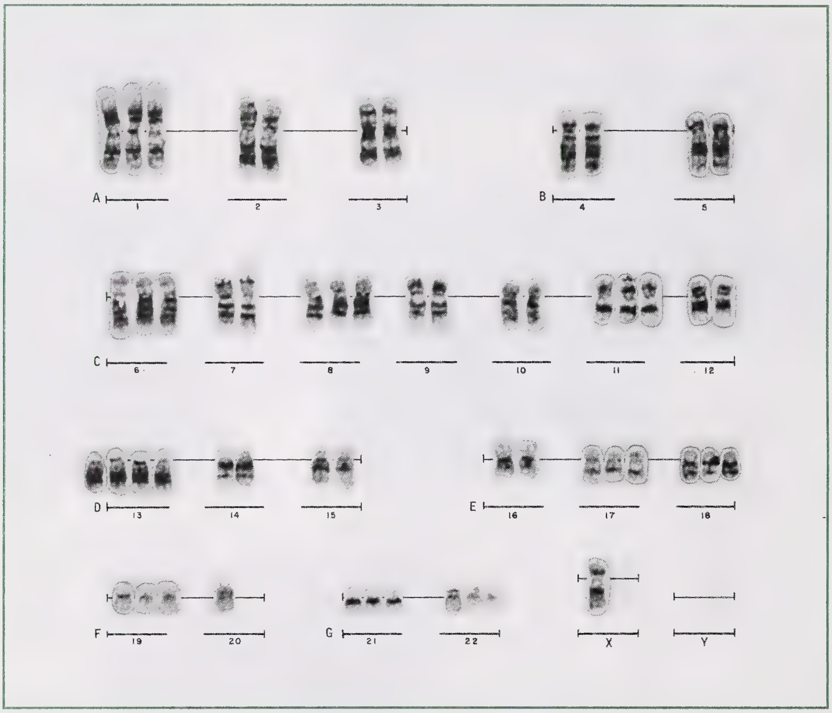
15. Carefully examine this karyotype of chronic myelogenous leukemia. **(4 marks)**

    a. Find the total number of chromosomes.

    b. Identify all occurrences of trisomy.

    c. Tetraploidy occurs as four chromosomes of one kind. Which chromosome illustrates tetraploidy?

    d. Which chromosomes are missing from the karyotype?



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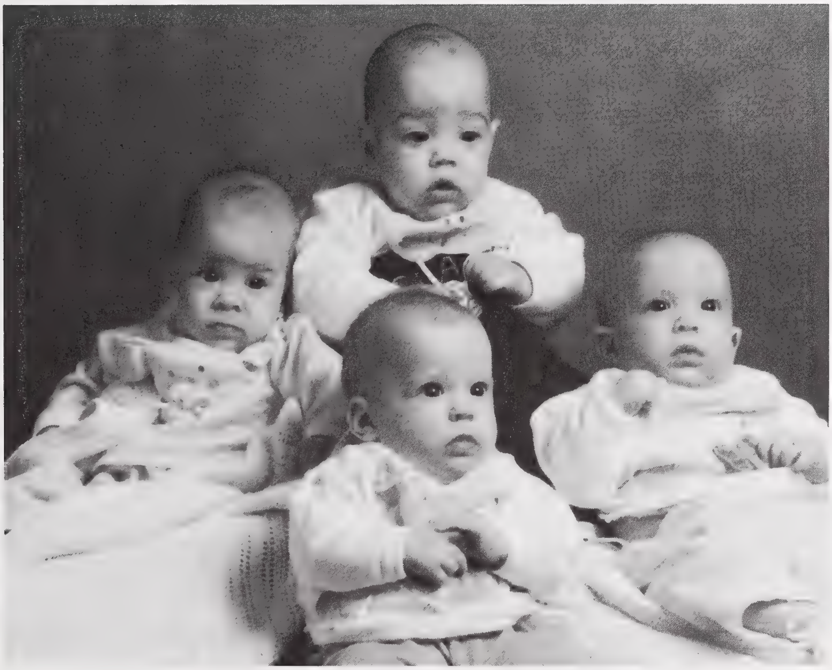
Reproduce the science skills assessment box after your response to this question. Remember to indicate your evaluation of your skill level for each identified science skill. Be sure to include the spaces for teacher assessment.

Self:	A. ☐	B. ☐	C. ☐	D. ☐	E. ☐	F. ☐
Teacher:	A. ☐	B. ☐	C. ☐	D. ☐	E. ☐	F. ☐

SECTION

2 Sex Cell Production

Karen used the birth control pill for the first five years of her marriage. When she and her husband John were ready to have children, Karen was unable to conceive. Finally, on the recommendation of their family doctor, Karen saw a specialist who put her on a drug to stimulate egg production. At first nothing happened, so the dosage of the drug was increased. The good news came a few months later that Karen was pregnant, but some time passed before the potential parents realized just how pregnant she was. Karen was going to have quadruplets.

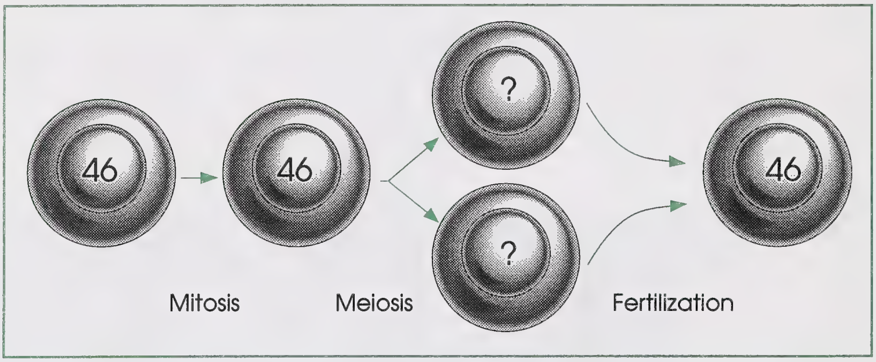


This section will deal with the formation of the special cells in males and females needed for sexual reproduction. The details of the cell division that produces sex cells will be covered and compared to mitosis. You will study both normal and abnormal processes that determine the genetic content of gametes before fertilization. And finally, you will compare the reproductive strategies used by organisms to ensure a continuance of their kind.

ACTIVITY

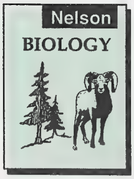
1 Principles of Meiosis

Can you add two and two? How about four and four, or forty-six and forty-six? Your answers likely are four, eight, and ninety-two. Would you be surprised if two plus two equalled two, or forty-six and forty-six still equalled forty-six? In sexual reproduction the problem of adding chromosomes from each parent without increasing the total number is solved.



Look at it this way. In mitosis, as you learned in Section 1, cells duplicate their genetic material and then divide. This makes two cells identical to the cell in the beginning. Now think about sexual reproduction. Could egg and sperm form this way? If they did, what would happen at fertilization?

Human cells have forty-six chromosomes. By doubling before dividing in mitosis, each daughter cell also gets forty-six chromosomes. What would happen if two daughter cells united like a sperm and ovum?



Check Figure 19.2 on page 449 in your text and read about the importance of meiosis on pages 448 to 449.

1. a. How many chromosomes are in the cells formed by mitosis?

   b. How many chromosomes are in the cells formed by meiosis?

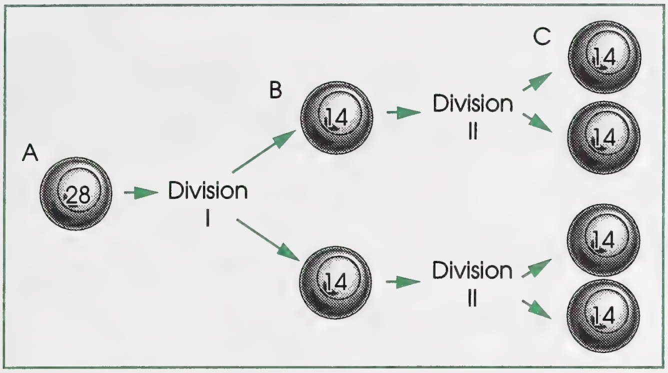
   c. Gametes or sperm and egg join at fertilization. How many chromosomes will be in the fertilized egg?

The terms *diploid* and *haploid* refer to the chromosome number in a cell.

2. a. Distinguish between a haploid cell and a diploid cell.

b. Which cells in your body are diploid and which are haploid?

Study the following flowchart of meiosis in order to answer question 3.



3. a. Use the correct letter to identify the cell(s) that is (are):

   i. diploid (2n)   ii. haploid (n)   iii. sex cells (gametes)

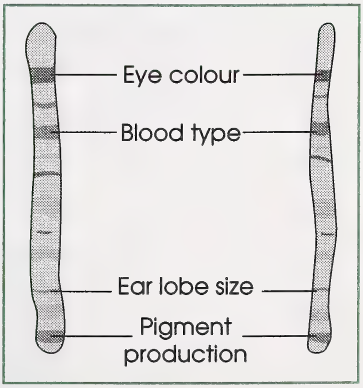
   b. How many divisions are there in meiosis?

In sexual reproduction, each parent contributes one set of chromosomes to an offspring. For convenience, a set of chromosomes will be defined as a collection of one of each kind of chromosome. For example, in humans there are twenty-three different kinds of chromosomes. This makes up a set. Since you get one set from each parent, you end up with two chromosomes of each kind.

4. What are these pairs of chromosomes called? How are they similar?

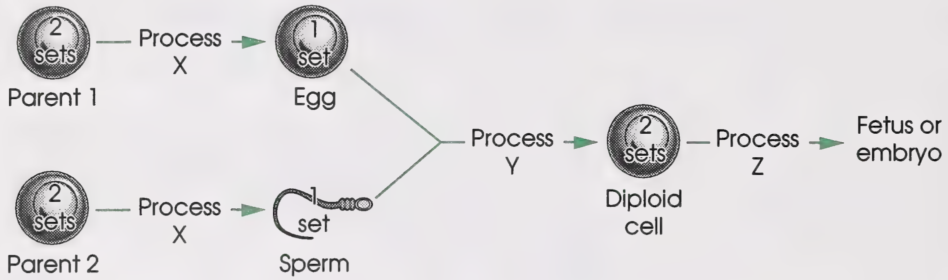
Nelson BIOLOGY

The homologous chromosomes shown in Figure 19.3 on page 450 of your text look different because they have already replicated. Notice the centromeres and the chromatids.



5. Can you think of one advantage of having two sets of chromosomes instead of one set?

Use this flowchart to answer question 6.



Science Skills

☐ A. Initiating
☐ B. Collecting
☐ C. Organizing
☑ D. Analysing
☐ E. Synthesizing
☐ F. Evaluating

6. a. Which process would be identified as meiosis? How can you tell?
   b. What is the purpose of meiosis?
   c. Identify Process Y and explain the purpose it serves.
   d. Name Process Z and explain why it must occur here.

Meiosis involves two divisions: meiosis I, called reduction division, separates the homologous pairs; and meiosis II, a normal mitotic division, separates the chromatids. To understand the entire process requires that you look at the details of each phase.

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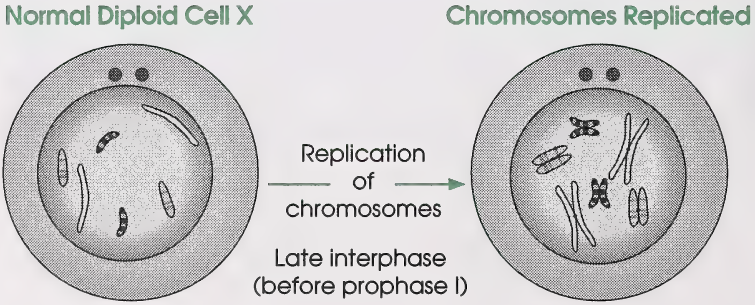
Read about meiosis I in the section entitled Stages of Meiosis on pages 449 to 451 of your text.

7. Name the four phases of meiosis I.

Check your answers by turning to the Appendix, Section 2: Activity 1.

Meiosis begins in exactly the same way as mitosis with the replication of each chromosome to produce two joined chromatids. This happens during the latter stages of interphase in a normal diploid cell found in the testes or ovaries of a plant or animal. Go back to Section 1 for an illustration of chromosome replication.


Normal Diploid Cell X
Chromosomes Replicated
Replication of chromosomes
Late interphase (before prophase I)

The chromosomes are long thin strands at this stage but are shown as shortened visible bodies for convenience.

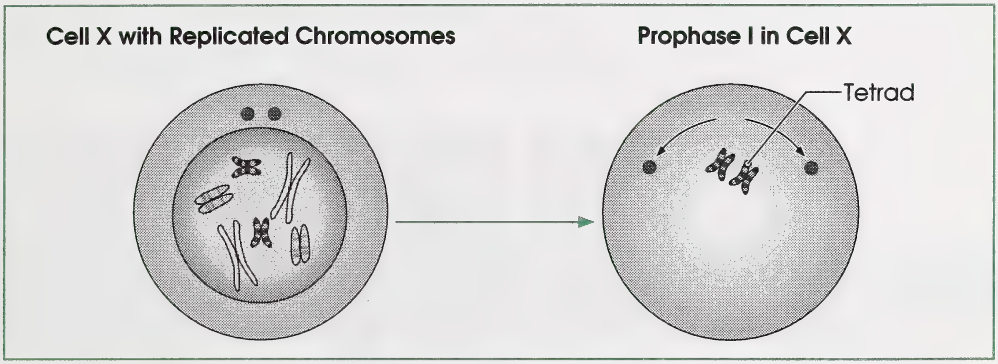
8. How many pairs of homologous chromosomes are shown in Cell X? Sketch them and label them by number.

Check your answers by turning to the Appendix, Section 2: Activity 1.

Once the chromosomes have replicated, the cell is ready for meiosis I.

9. List the significant events that occur in Prophase I. (These are identical to the events of prophase in mitosis.)

Prophase of Meiosis I

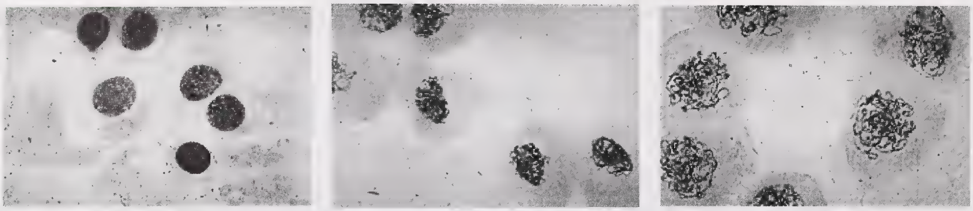


10. In the previous diagram one tetrad is drawn in for you in Cell X. Draw in the other two tetrads that would form.

The sketch of the tetrad in Cell X shows homologous chromosomes, each formed of two chromatids, lying side by side. This has been done deliberately so that you can see the four chromatids. During this stage the chromatids of homologous chromosomes are actually intertwined. This leads to breakages in the chromatids which have to be repaired by enzymes. Examine Figure 19.4 on page 450 of your text and answer the next question.

11. a. Explain the processes of synapsis and crossing-over.
    b. Explain how crossing-over contributes to genetic diversity.

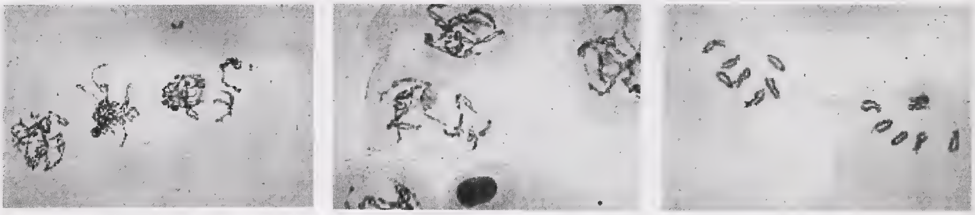
Once the spindle fibres form and attach to the centromeres of each homologous chromosome, prophase I progresses into metaphase I. These cells have gone from interphase through prophase. Compare the cells in the following three microphotographs. Notice that the chromosomes in the third photo are easy to see but would be hard to count. Next the cells go into metaphase.


[1]

12. a. Using Cell X from the previous questions, draw the tetrads in Cell X as they would appear in metaphase I.

Metaphase is a short phase that quickly progresses to anaphase. A very important event occurs in metaphase that suddenly makes the chromosomes more easily distinguished. In each of these cells you can see the chromosomes progressively shorten then line up prior to separating. Finally the chromosomes can be counted.

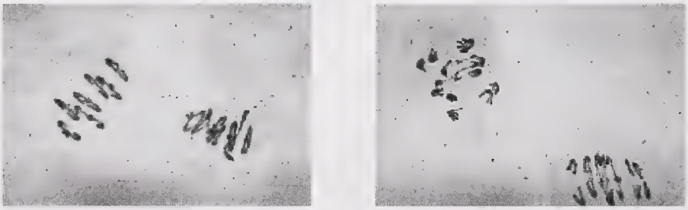
b. Examine the cells in the following microphotographs as they progress from prophase I to metaphase I. How many chromosomes can be counted in each cell in the third photo? Look for this number in the following photos.


[2]

13. a. The process of segregation occurs in anaphase I. Explain this process.

b. Illustrate segregation in Cell X.

Telophase I follows anaphase I. An important occurrence during telophase I is cytokinesis. Once it is complete, two cells are formed. These processes can be seen in the following microphotographs.


[3]

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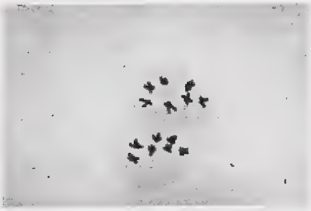
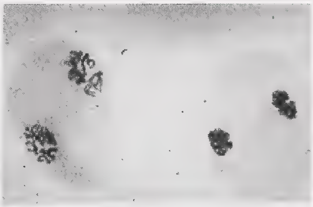
[1] This row of photographs courtesy of J. Kuspira and R. Bhambhani, Department of Genetics, University of Alberta.

[2] Ibid.

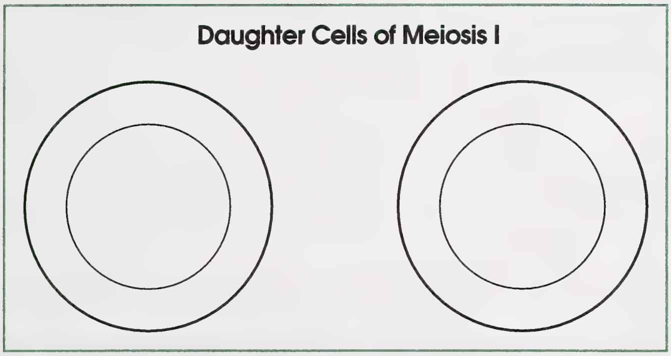
[3] Ibid.





[1]

14. Draw a sketch of the chromatid pairs in the nucleus of each of the daughter cells formed from meiosis I of Cell X.



Check your answers by turning to the Appendix, Section 2: Activity 1.

The two daughter cells of meiosis I now go into meiotic interphase during which they prepare themselves for meiosis II yet to come. This can be an extremely brief or an extremely long phase depending on the organism. Replication of chromosomes does not occur during this phase.

To get some understanding of what happens in the second division of meiosis, read the section entitled Meiosis II on page 451 and study Figure 19.6.

In meiosis I the homologous chromosomes were separated. Now there is only one of each kind of chromosome in the daughter cells instead of two. However, the chromosomes had originally replicated before meiosis started; thus, there is one more division that must occur to complete the process of gamete formation.

15. What bodies of genetic material are separated in meiosis II?

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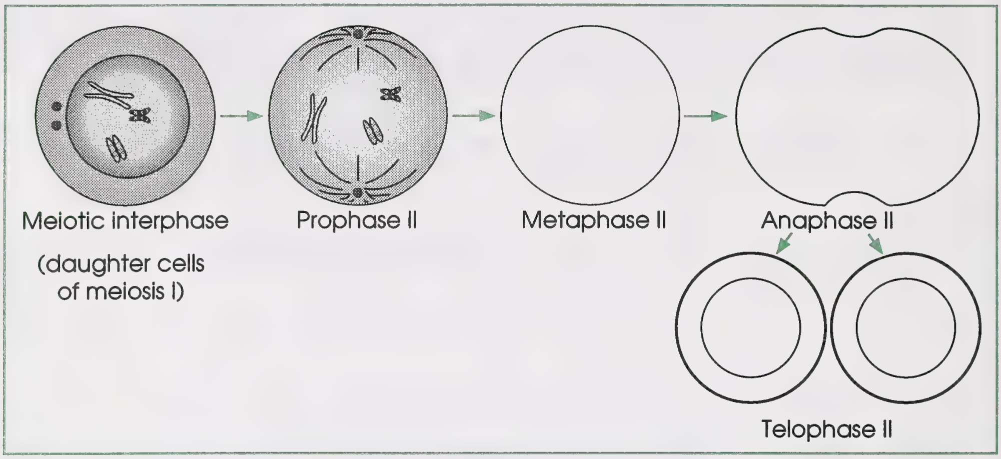
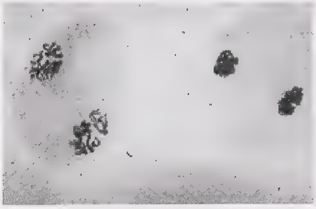
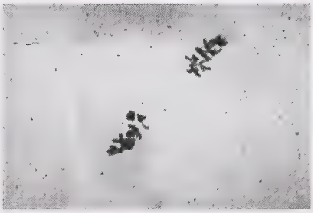
[1] This row of photographs courtesy of J. Kuspira and R. Bhambhani, Department of Genetics, University of Alberta.

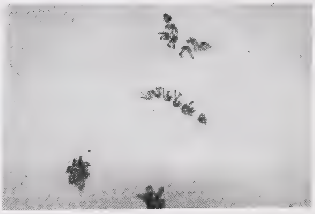
16. a. Draw a sketch of metaphase II, anaphase II, and telophase II of meiosis II for one daughter cell of Cell X. Remember, the second daughter cell goes through the same process.



b. Use your sketches to name the phases in meiosis II for each of these photos.

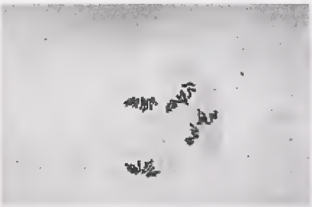


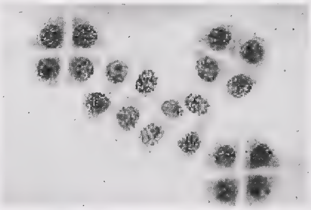


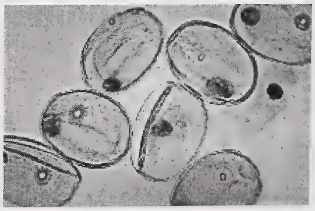


[1]

i. ______________________ ii. ______________________ iii. ______________________







[2]

iv. ______________________ v. ______________________ vi. ______________________

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[1] This row of photographs courtesy of J. Kuspira and R. Bhambhani, Department of Genetics, University of Alberta.

[2] Ibid.

c. How many chromosomes can be seen in the cells in the third photo?

d. Sketch and number the chromosomes from a cell in the third photo.

Meiosis in Cell X is now complete.

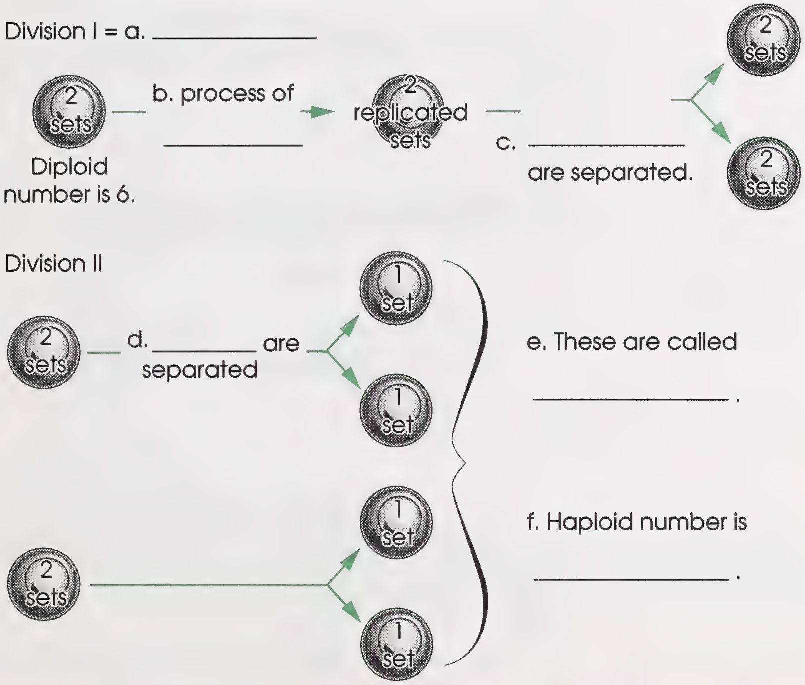
17. a. How many cells are produced from the meiotic division of Cell X?

b. How is the genetic composition of the cells produced different from the original mother Cell X?

c. What is the function of cells produced by meiosis?

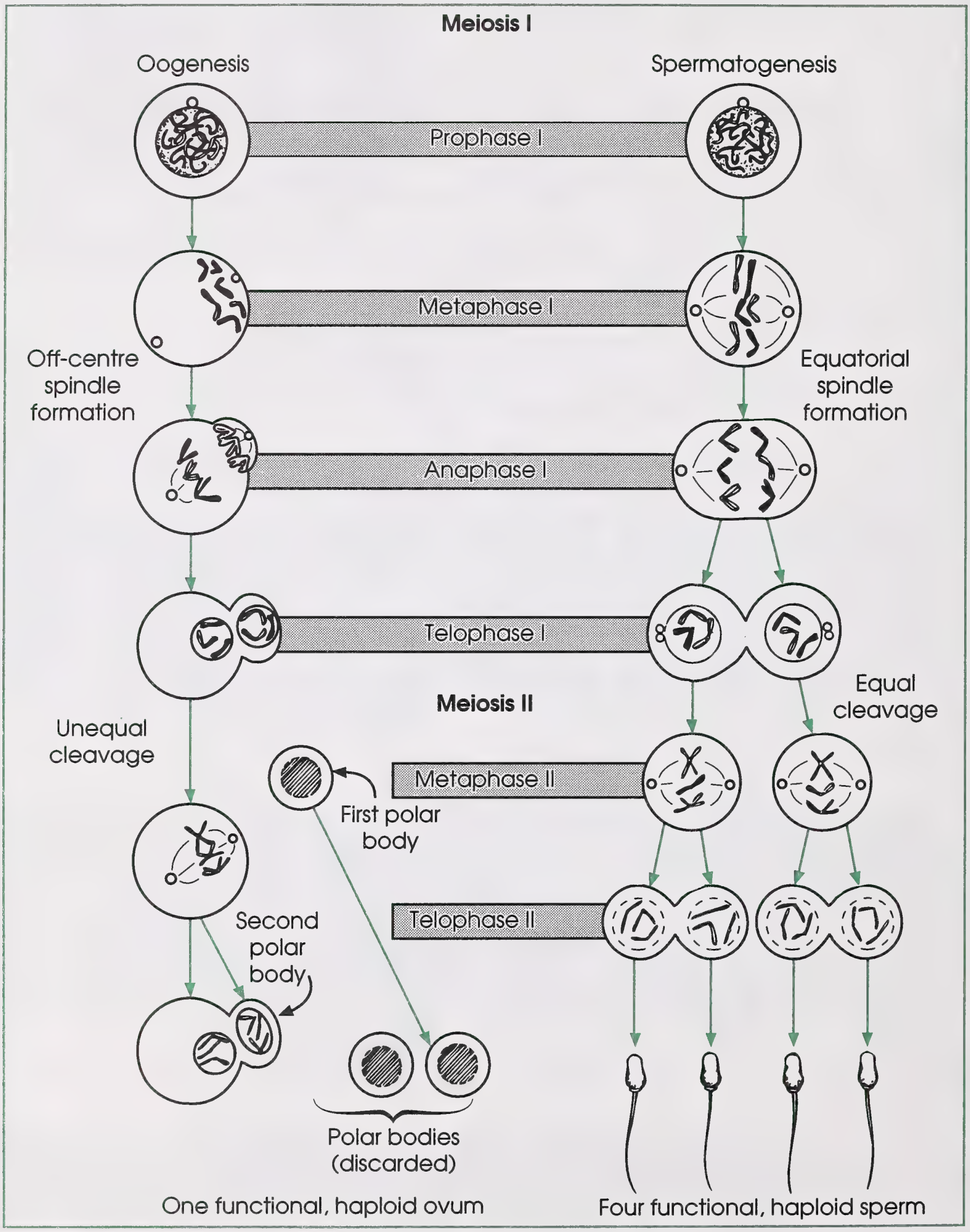
d. The sex cells produced by meiosis are known by three other names. What are the names?

18. Complete the flowchart which summarizes meiosis of a cell with a diploid number of 6. Use any of these terms: *homologous chromosomes, chromatids, replication, reduction division, gametes, 3, 6, 12.*


Division I = a. ____________
2 sets
Diploid number is 6.
b. process of ____________
2 replicated sets
c. ____________ are separated.
2 sets
2 sets
Division II
2 sets
d. ________ are separated
1 set
1 set
1 set
1 set
2 sets
e. These are called ____________ .
f. Haploid number is ____________ .

Check your answers by turning to the Appendix, Section 2: Activity 1.

Although meiosis is similar in both males and females, there are some distinct differences. Read the section entitled Development of Male and Female Gametes on pages 452 and 453 of your text to learn more about these differences. Use Figure 19.7 for information to complete the next question.



19. Construct a table comparing gametogenesis in human males and females. Make your table similar to this one.

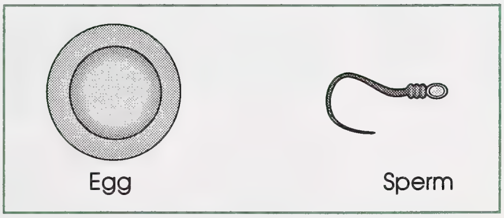
Gametogenesis in Humans		
	Males	**Females**
Structure in which it occurs		
Name of process		
Name of cell that begins meiosis		
Cytokinesis (equal/unequal)		
Number of functional gametes produced per division		
Name of cells produced		
Relative size of cells produced		

The one egg produced by a meiotic division receives most of the cytoplasm. The other cells, called polar bodies, get little more than a set of chromosomes to make a nucleus.

20. a. Explain why the egg cell needs all this cytoplasm and why the sperm cell does not.

    b. What happens to the polar bodies?

    c. What could happen if a polar body did not separate from the egg prior to fertilization?



21. Compare the number of gametes produced by males to those produced by females over their lifetime.

22. A man can potentially father a child well into his sixties and seventies, whereas a woman usually cannot bear children past the age of about fifty years. Explain the difference.

Check your answers by turning to the Appendix, Section 2: Activity 1.

At this point you have probably assumed that there are always twenty-three pairs of homologous chromosomes in normal human beings. This is true for females but not for males. In males there are twenty-two homologous pairs, but the last two chromosomes differ in size and shape.

If you have access to a microslide viewer and slide set 62 Reproduction (Human), view Slide 5 to see these chromosomes. Try to count them.

Find out more about these non-homologous chromosomes found in males, first discovered by Thomas Hunt Morgan, by reading pages 452 and 453 of your text.

23. What did Morgan call these two chromosomes that were paired in females but not in males?

24. a. Give the chromosome combination that produces females.

    b. Give the chromosome combination that produces males.

25. What are autosomes and how many pairs of them are there in normal human cells of both sexes?

26. a. Describe the sex chromosomes in ova and sperm.

    b. From which parent does a male child get his X chromosome, his mother or father?

Science Skills

☐ A. Initiating
☐ B. Collecting
☐ C. Organizing
☐ D. Analysing
☑ E. Synthesizing
☐ F. Evaluating

Check your answers by turning to the Appendix, Section 2: Activity 1.

The X and the Y chromosomes are not homologous even though they behave as though they are during meiosis. The fact is, they do not carry genes for the same traits. You will see the significance of this when you study the inheritance of traits controlled by genes located on the X and Y chromosomes discussed in Module 5.

You have looked at mitosis in some detail in the previous section. How does it compare to the process of meiosis? This comparison is the topic of the next activity.

ACTIVITY

2 Comparison of Mitosis and Meiosis

How is it that cells seem to know what kind of cell division to perform? Imagine cutting your toe, and the cells surrounding the damaged tissue reproduced by meiosis instead of mitosis. What would you have, a reproductive toe?

Mitosis occurs to produce more cells of the same kind. This normal cell division can occur in cells with one, two, three, or more chromosomes. Meiosis can occur in cells only with an even number of chromosomes where there are homologous pairs that can match up to form tetrads.

Investigation: Comparing Meiosis and Mitosis

Objective

The objective of this investigation is to use models to compare the events of meiosis and mitosis.

Nelson
BIOLOGY

Materials

In addition to the list of materials on page 454 of your text you will need tape.

Science Skills

☑ A. Initiating
☐ B. Collecting
☑ C. Organizing
☑ D. Analysing
☐ E. Synthesizing
☑ F. Evaluating

Procedure

Mitosis

- Follow the procedure given in the text.
- Answer the questions as you work through the investigation.

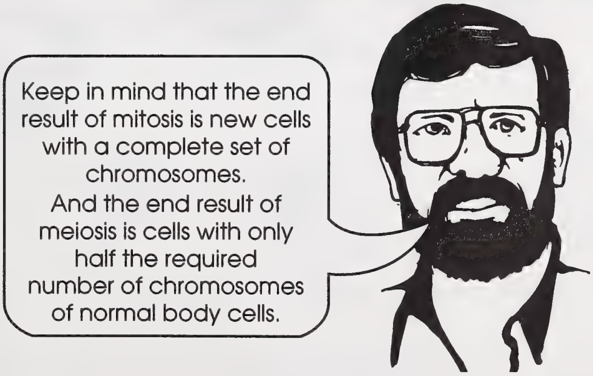
1. Do Procedure questions a to e found on page 454.

Meiosis

- Follow the procedure given in the text.
- Answer the questions as you work through the activity.

2. Do Procedure questions f to k found on page 454.

Check your answers by turning to the Appendix, Section 2: Activity 2.


Keep in mind that the end result of mitosis is new cells with a complete set of chromosomes. And the end result of meiosis is cells with only half the required number of chromosomes of normal body cells.

Nelson
BIOLOGY

Compare telophase in Figure 18.6 on page 434 to telophase II in Figure 19.6 on page 451 in your text.

Meiotic cell division is under the influence of certain hormones secreted by the body. As you learned in Module 2, these hormones are released at puberty and sexual maturation results.

Meiosis is a much more complicated process than mitosis. Considering all the phases of chromosome pairing, crossing-over, and double division, you shouldn't be surprised to learn that frequently something goes wrong.

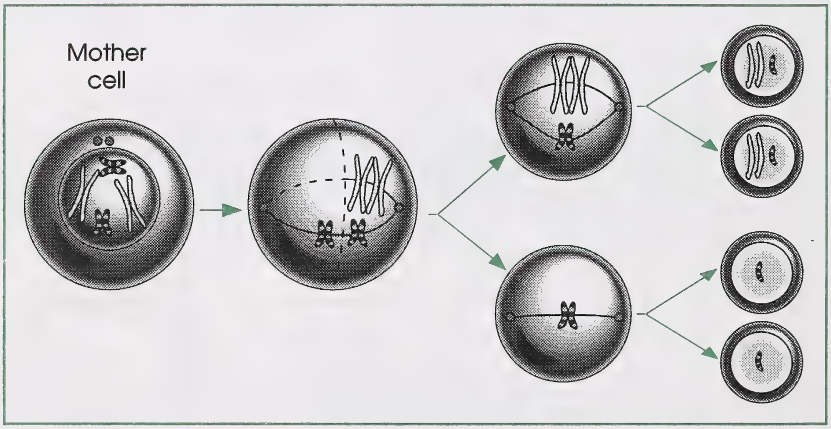
ACTIVITY

3 Abnormal Meiosis

Homologous chromosomes and chromatids sometimes do not separate during meiosis so the resulting gametes end up with more than twenty-three chromosomes or less than the required number. This happens in both males and females.

Read the section entitled Abnormal Meiosis: Nondisjunction and Nondisjunction Disorders on pages 454 to 457.

Carefully study this illustration and then answer the question that follows.



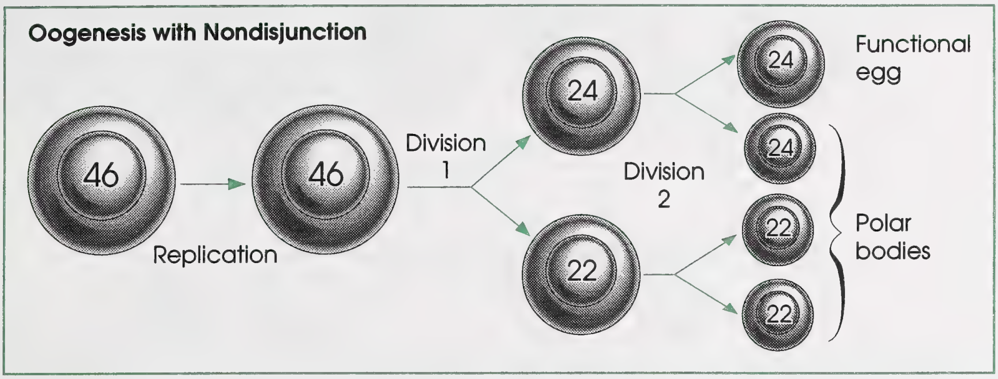
1. a. What has happened that is not normal? What is this process called?

   b. Sketch a normal gamete that should arise from the mother cell.

Nondisjunction can also occur during the second division of meiosis. During metaphase II the chromatids may fail to separate and again the resulting gamete may have one extra or one missing chromosome.

2. Name three genetic disorders that are the result of nondisjunction.

Use the flowchart showing the results of nondisjunction in meiosis I to answer question 3.


Oogenesis with Nondisjunction

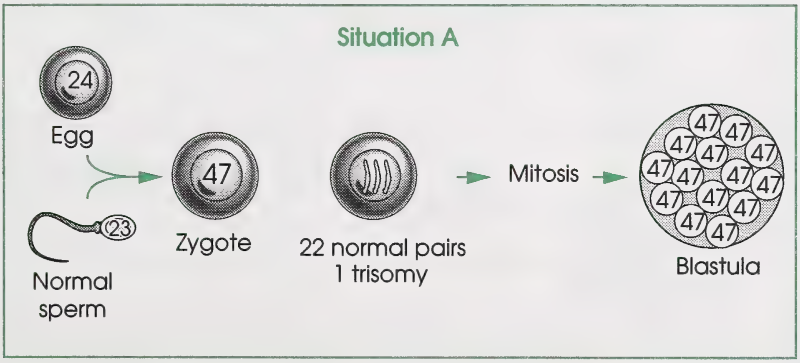
3. a. In which division has nondisjunction occurred?

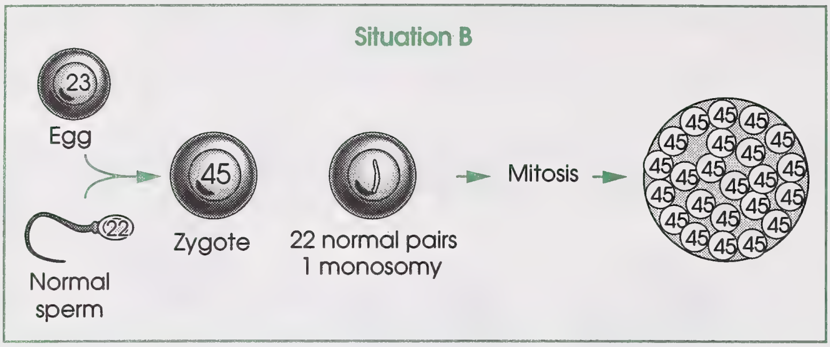
   b. Why is the egg cell shown abnormal?

   c. If the cell with twenty-two chromosomes were to give rise to the egg, would the egg be abnormal? Explain.

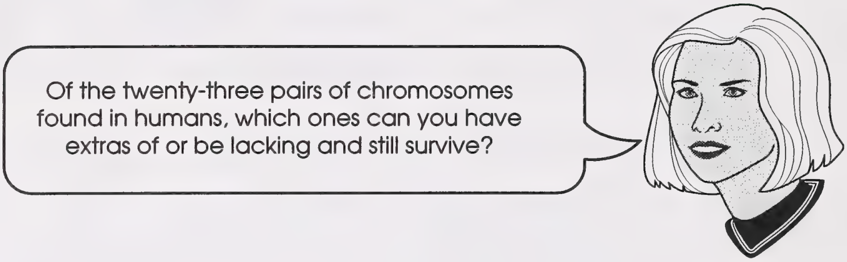
4. Zygotes having an abnormal number of chromosomes are usually described by the terms *monosomy* or *trisomy*. What do these terms mean?

Assume the eggs that could be produced from the division shown in question 3 are fertilized as illustrated.


Situation A


Situation B

5. Label each illustrated situation as either trisomy or monosomy.


Of the twenty-three pairs of chromosomes found in humans, which ones can you have extras of or be lacking and still survive?

Research shows that trisomy or monosomy of most chromosomes leads to spontaneous abortion early in human pregnancy. About a third of all pregnancies are aborted in the first two or three months because the embryos have the wrong number of chromosomes. But not all failures of meiosis result in early miscarriage. Approximately one baby in 200 has the wrong chromosome number and survives for some time. These individuals often have both physical and mental abnormalities. So what causes trisomy? For one answer read Research in Canada on page 457 of your text.

6. a. What factor was initially linked to nondisjunction?

   b. What factor was found to cause nondisjunction in fruit flies?

   c. How did Dr. Uchida link these two factors to form an hypothesis?

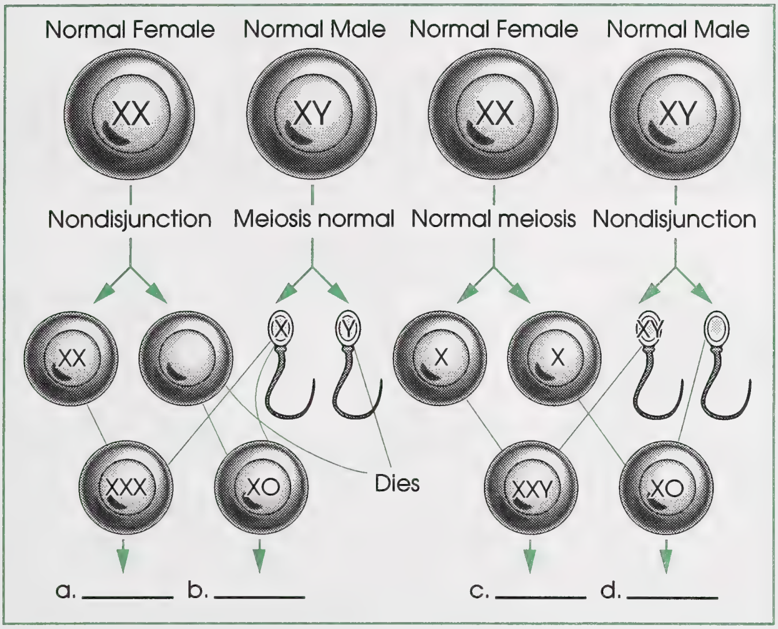
7. In most cases, how does the karyotype of an individual with Down syndrome differ from a normal karyotype?

8. Identify some of the symptoms of Down syndrome.

9. Examine the bar graph in Figure 19.10 on page 456 of your text. How does the incidence of Down syndrome change as the age of the mother increases?

Individuals with abnormal numbers of sex chromosomes may survive as long as at least one X chromosome is present.

10. Identify the syndrome produced by each of the abnormal sex chromosome combinations shown in the chart.



11. Some individuals may have the combination of sex chromosomes XXXY. What is the sex of this person and why?

Check your answers by turning to the Appendix, Section 2: Activity 3.

Developments in medical technology and practices now make it possible for parents to find out if the fetus being carried by the mother has certain genetic disorders such as Down syndrome. You have already learned about some diagnostic technologies in Module 3.

To review some of the techniques used, read Frontiers of Technology: Amniocentesis on page 458 of your text.

12. What three medical techniques are presently used by doctors to detect genetic disorders in humans associated with abnormal chromosome counts? Briefly describe these procedures.

New technologies are intended to solve problems but sometimes in doing so they create some major ethical concerns.

13. What limits or restrictions do you think should be put on these diagnostic techniques and the information they provide?

Investigation: Human Karyotypes

Science Skills

☐ A. Initiating
☑ B. Collecting
☑ C. Organizing
☑ D. Analysing
☑ E. Synthesizing
☐ F. Evaluating

Objective

The objective of this investigation is to use a karyotype to diagnose a genetic disorder.

Materials

See the list on page 459 of your text.

Procedure

- Follow the steps outlined on page 459 of your text.
- Do all the questions as you progress through the activity.

Observations

14. Prepare a karyotype chart from Human Karyotype Plate A at the end of the Appendix. Chromosome pairs in Karyotype Plate A should match closely to those shown on page 459 of the text.

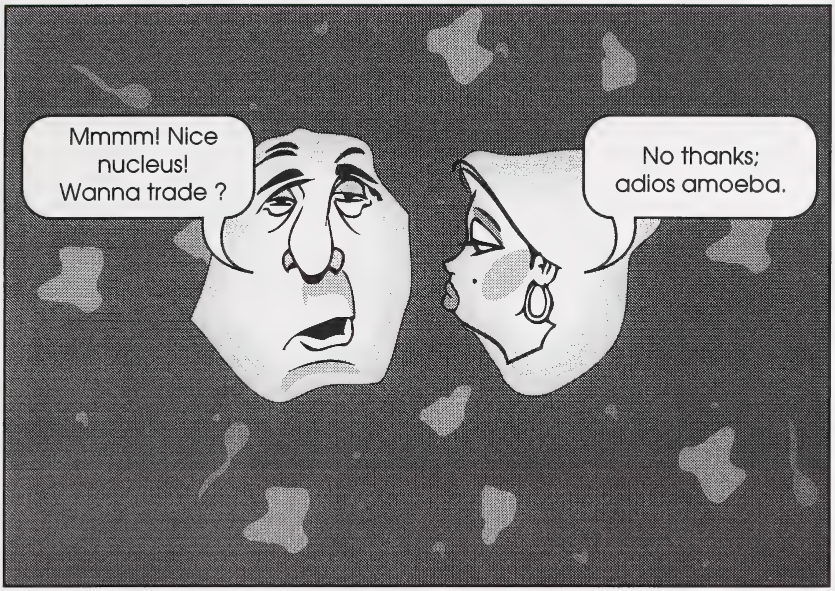
15. Answer the Procedure and Laboratory Application Questions on page 459.

Check your answers by turning to the Appendix, Section 2: Activity 3.

So now you've learned that mitosis produces more cells of the same kind. Meiosis produces gametes or sex cells with only half the chromosomes needed for life. At fertilization the gametes unite restoring the required chromosome number. Recall that cancer is associated with abnormal mitosis. Abnormal meiosis can result in irregular chromosome numbers in gametes. If these gametes participate in fertilization, various genetic syndromes result.

ACTIVITY

4 Reproductive Strategies of Organisms

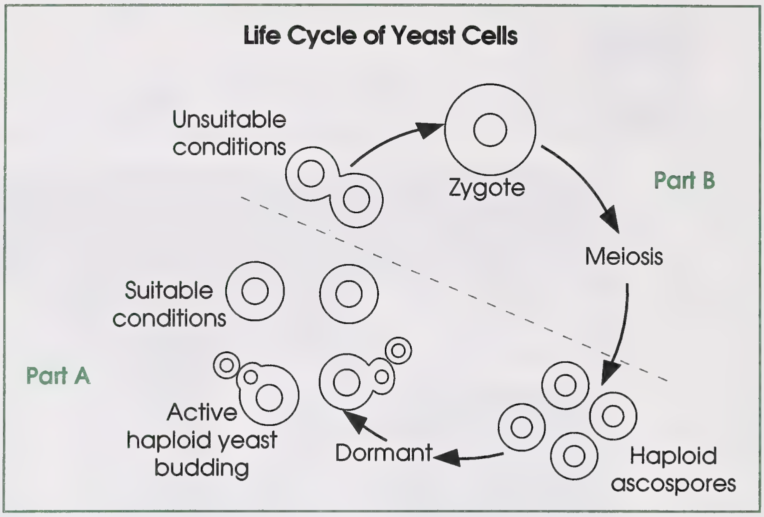

Mmmm! Nice nucleus! Wanna trade ?
No thanks; adios amoeba.

Nelson BIOLOGY

Meiosis and sexual reproduction create an opportunity for slight variations in species of organisms. You may recall from Biology 20 that variation is a key to adaptation and evolution. Sexual reproduction is common in most organisms you are familiar with. However in the world of living things a surprising number of other methods exist. Read the Biology Clip on page 449 in your text. This is not a complete story but it does show you some other possibilities.

In this activity you will study the ways in which a variety of organisms make use of sexual and asexual reproduction to propagate their kind. Many organisms alternate between sexual and asexual reproduction during their life and show a shift from the diploid to the haploid chromosome condition at certain stages of the life cycle.

The somatic or body cells of more complex plants and animals are diploid. In the lower forms of life this is not always the case. For example, the active cells of yeast exist as haploid cells. When conditions are right they rapidly clone themselves by the process called budding. If the conditions become unsuitable, yeast cells will fuse forming diploid cells. These cells then go through a meiotic division to form haploid ascospores that remain dormant until the conditions improve again. The yeast that you can buy in stores is the ascospores.



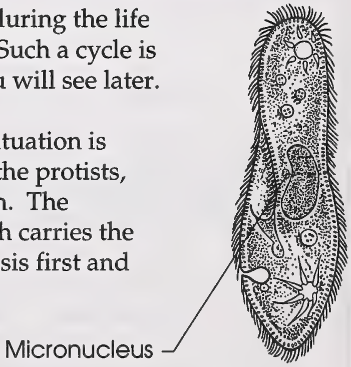
1. What kind of cell division is involved in the budding process? Explain.
2. When a yeast cell undergoes meiosis how many ascospores are produced? Is this consistent with what you would expect for this kind of division? Explain.
3. The life cycle of yeasts can be divided into two phases. Which one is the sexual phase and which one is the asexual phase?
4. What seems to trigger sexual reproduction in yeast cells?

Check your answers by turning to the Appendix, Section 2: Activity 4.

alternation of generation – a life cycle involving a sexual phase and an asexual phase

The regular change from sexual to asexual reproduction during the life cycle of an organism is called **alternation of generation**. Such a cycle is characteristic of simple organisms and some plants as you will see later.

In the single-celled protists such as the paramecium the situation is somewhat different from that of the yeast. Like many of the protists, paramecia normally reproduce asexually by binary fission. The chromosome number is diploid in the micronucleus which carries the hereditary genetic material. This nucleus divides by mitosis first and division of other cellular components follows.

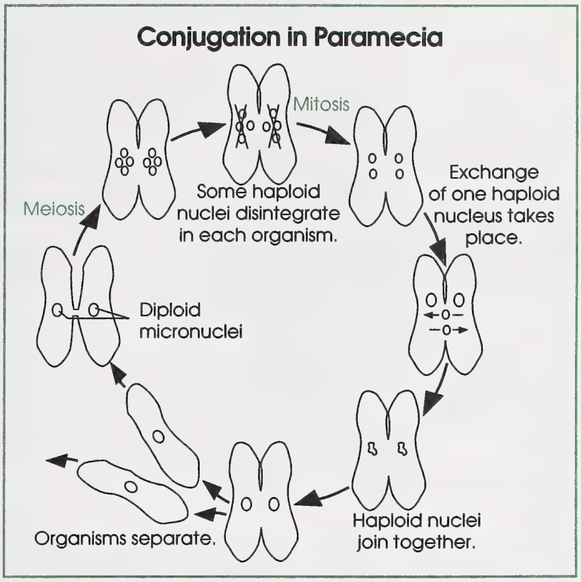


When a paramecium comes upon another individual of a different mating type, it will join with that organism and undergo a form of sexual reproduction called **conjugation**. This process is summarized in the flowchart on the right.

conjugation – a form of sexual reproduction in which genetic material is exchanged between two organisms but there is no increase in the number of organisms

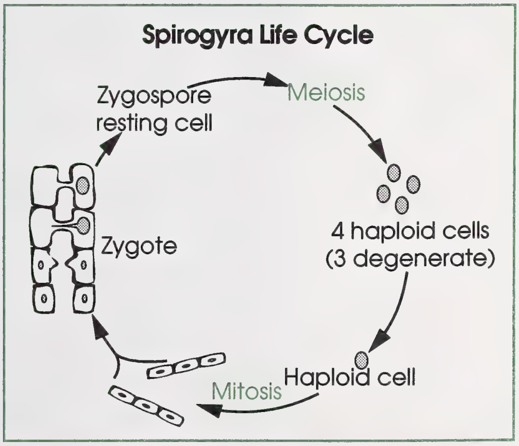
Reproduction generally results in an increase in number of individuals. Conjugation doesn't appear to do this; it just changes the genetic makeup of individuals.

5. What is the purpose of conjugation?
6. What is the general form of reproduction used by paramecia?


Conjugation in Paramecia
Mitosis
Meiosis
Some haploid nuclei disintegrate in each organism.
Exchange of one haploid nucleus takes place.
Diploid micronuclei
Haploid nuclei join together.
Organisms separate.

In simple plants such as green algae the cycle of reproduction reflects a sequence similar to the yeast. In *Spirogyra*, a freshwater algae, the cells that make up the strand of the plant are haploid. Normally new cells are added to the strand by mitosis and these break off by wave action or other physical forces. This process is called fragmentation. When conditions become unfavourable, *Spirogyra* will conjugate. The cycle of events is summarized in the following diagram.

7. In this cycle, what event represents the beginning of the sexual phase of reproduction?
8. The fusion of the two haploid nuclei during conjugation of *Spirogyra* is equivalent to what process that takes place in complex plants and animals?
9. How is the haploid condition restored in the cells that make up the next generation of *Spirogyra* strands?



Check your answers by turning to the Appendix, Section 2: Activity 4.

Reproductive patterns in other simple plants show a striking similarity to the life cycle of the *Spirogyra*. Moss plants in the Alberta forests consist of cells that are haploid. These plants reproduce sexually, producing sperm and egg in special structures at the tips of the plants. Moss plants are called **gametophytes** because they produce gametes for reproduction and they consist of haploid cells. The gametophyte stage is the dominant stage in the mosses' life cycle. The male gametophyte produces sperm. The female gametophyte produces an egg.

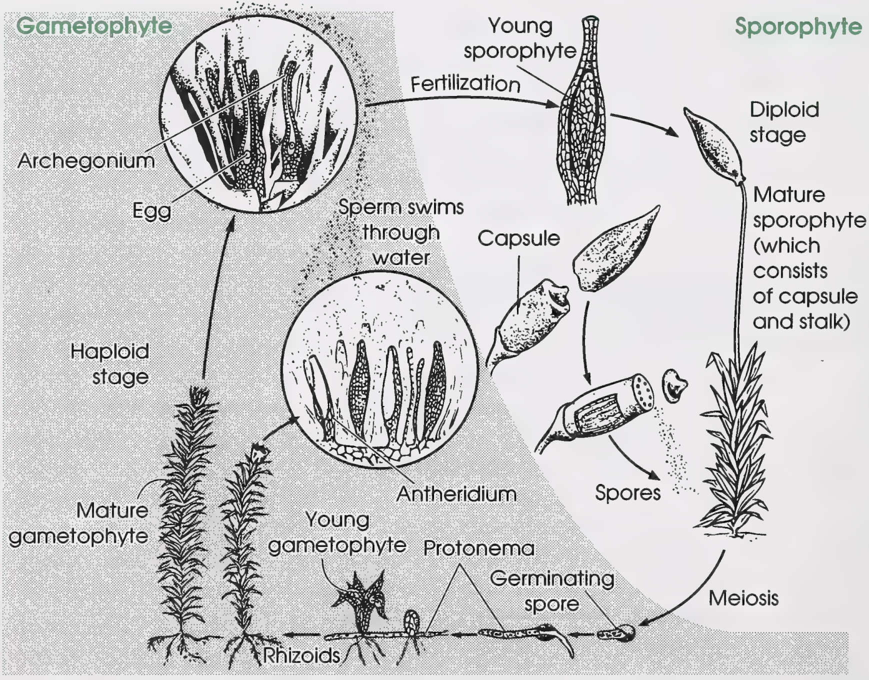
gametophyte – the haploid stage of a plant that produces gametes which join and produce the sporophyte generation

The sperm swims to the egg cell through a film of water, and when fertilization occurs the resulting zygote cell grows into a **sporophyte** consisting of a stalk and capsule. A sporophyte is diploid and produces spores for reproduction.

sporophyte – the diploid stage of a plant that undergoes meiosis and produces spores for reproduction of the gametophyte generation

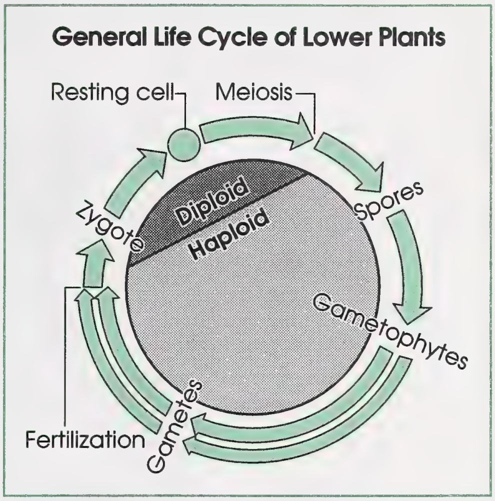
This stalk and capsule consists of diploid cells because it originates from a diploid zygote that actively divides mitotically. The capsule produces haploid spores that are released into the air when they mature. If they find a suitable site to grow, they develop into a new gemetophyte moss plant. The life cycle of a moss is summarized in the following flowchart.

Moss Life Cycle



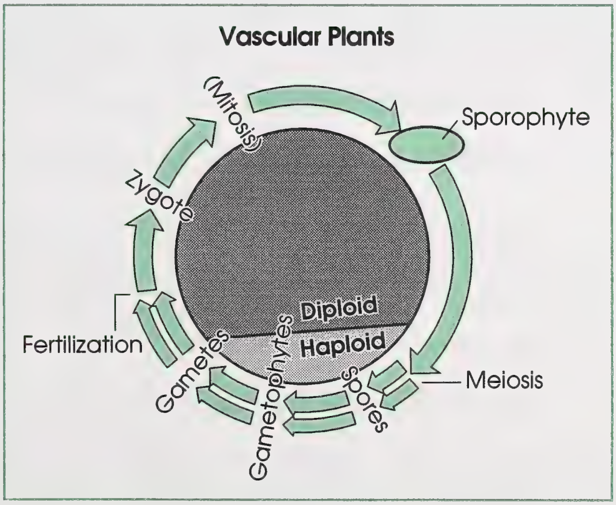
10. What kind of cell division is involved in the production of gametes in mosses? Explain why.

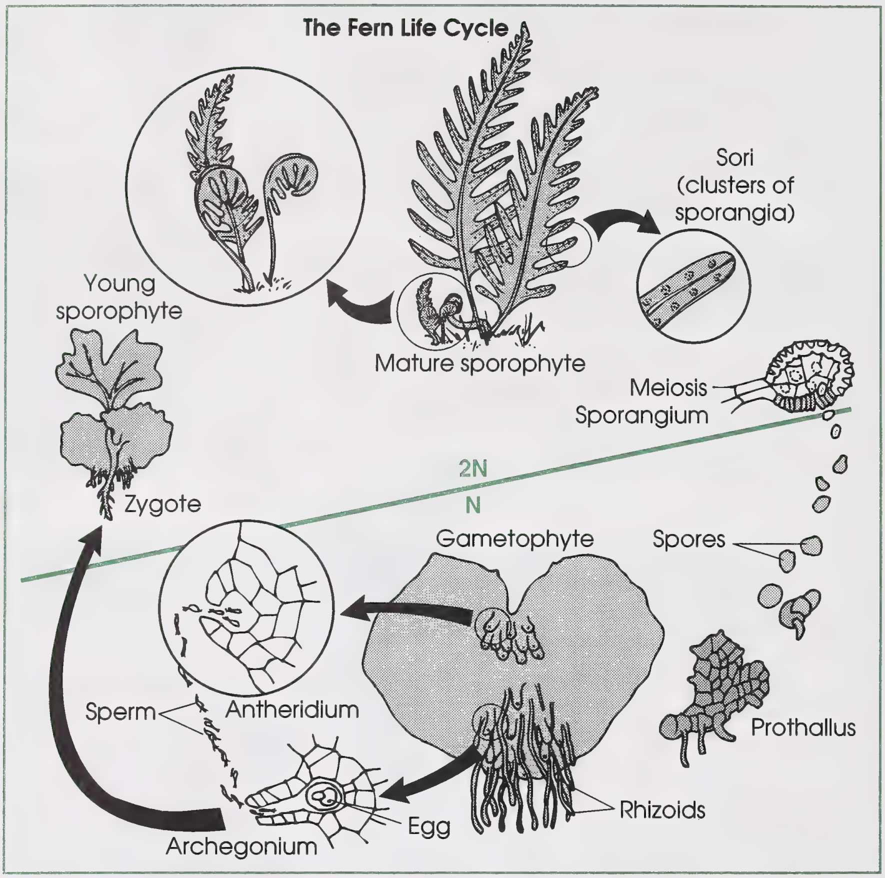
11. Identify in mosses the reproductive units produced by the process and the structure where meiotic divisions occur.
12. Why do mosses need moist conditions to reproduce?
13. With regards to dispersal, what is the advantage of producing spores?
14. Is the dominant stage in a moss's life cycle haploid or diploid?



Check your answers by turning to the Appendix, Section 2: Activity 4.

In the more advanced vascular plants such as ferns, flowering plants, and the cone-bearing plants, the dominant stage is diploid. The grasses, trees, weeds, and other plants that you commonly see in Alberta are sporophytes. What has happened to the gametophyte stage? Why has nature shifted from the dominant gametophyte stage you saw in the lower plant forms to the diploid sporophyte stage in the more complex plants?





15. Use the fern life cycle to answer the following questions.

   a. Is the dominant stage of a fern plant a gametophyte or a sporophyte?

   b. Are the cells of a fern plant diploid or haploid?

   c. Do fern plants produce gametes or spores for reproduction?

   d. Are spores produced by meiosis or mitosis?

   e. Are spores haploid or diploid?

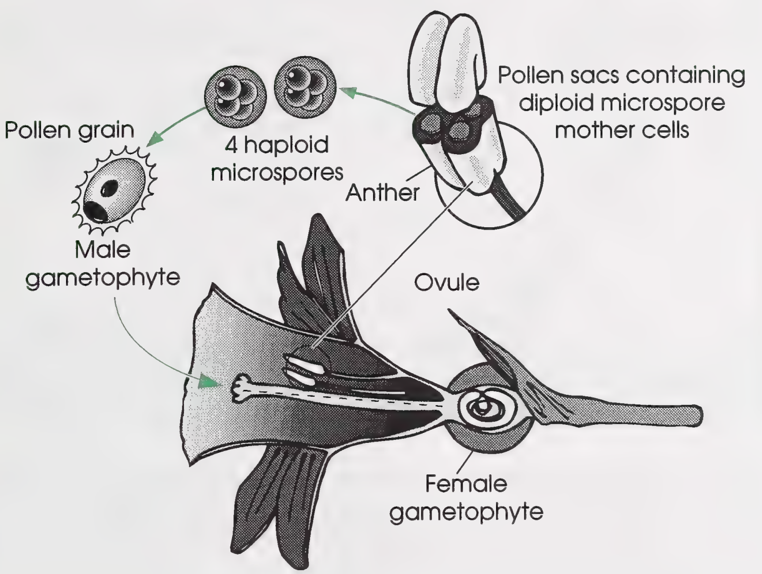
   f. Is a small prothallus a gametophyte or sporophyte?

   g. Does the heart-shaped prothallus produce gametes or spores?

   h. Does the zygote grow into a sporophyte or gametophyte?

In plants that produce seeds, the gametophyte has been reduced to microscopic structures. The male gametophyte is the pollen grain and the female gametophyte is the ovule.

Gametophytes of Flowering Plants



In the higher plants the sperm does not need a film of water through which it swims to the egg. Instead, the sperm nucleus is confined to a protective case called the pollen grain which can be transported about by wind, water, insects, birds, and bats. For fertilization to occur, the pollen grain must be transferred from the male anther to the stigma of the female pistil. This transfer is called pollination.

ollination – ransfer of pollen rom the anther o the stigma of a lower

16. What is the advantage of confining sperm cells to pollen grains instead of allowing them to be free-swimming?

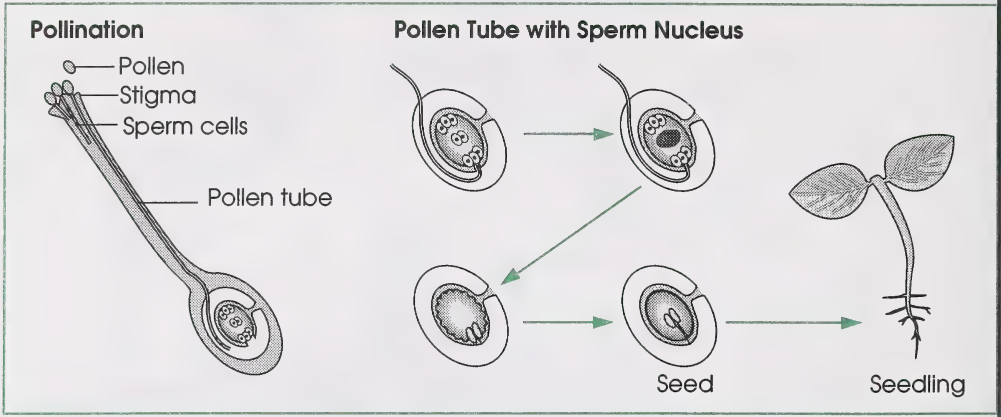
Some plants allow the pollen of the same flower or other flowers on the same plant to pollinate the pistils. This bypasses the difficulty of getting pollen from other plants of the same species to reach these particular flowers and it ensures that seeds will be produced. Such a strategy is called self-pollination.

17. Can you see the disadvantage in self-pollination? What is it?

Cross-pollination is predominant among flowering plants. This requires an agent or means of getting the pollen from one plant to another. Some plants rely on the wind; others on water; and still others on insects, birds, or bats as the agent of pollination.

18. What does the flower produce that attracts these organisms so that they may transfer pollen from flower to flower ensuring cross-pollination and cross-fertilization?

Once pollination occurs a pollen tube grows down the pistil carrying the sperm nucleus to the egg in the ovule. Here fertilization will occur to form a zygote.


Pollination

Pollen Tube with Sperm Nucleus

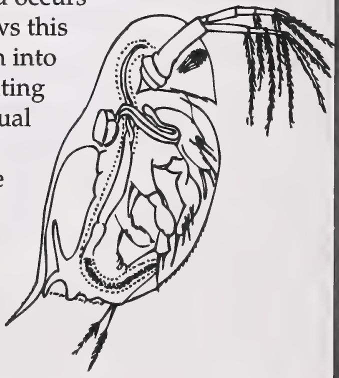
The diploid zygote rapidly undergoes mitotic divisions growing into an embryo plant. Along with the embryo plant grows a tissue filled with nutrients. These all are encased in a tough coat forming a seed which can germinate into a new plant if it falls in a suitable place.

19. What are some ways that seeds are dispersed?

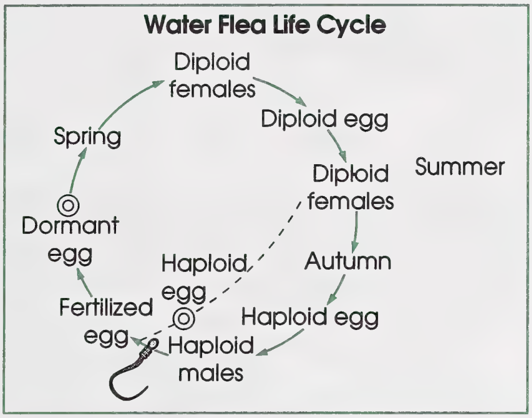
Although there are exceptions, animals by and large rely on sexual reproduction and are diploid.

20. Suggest one reason why the more complex plants and animals need to be diploid rather than haploid.

In the animal kingdom, alternation of generation is rare and occurs in a modified form. The common water flea (*Daphnia*) shows this unusual cycle. During the spring, all the diploid eggs hatch into females. These females lay diploid eggs all summer generating an entire summer population of diploid females. This asexual phase of the water flea's life cycle generates enormous populations of the freshwater crustacean. The sexual phase begins in the fall. The colder temperatures stimulate the females to begin laying haploid eggs. These hatch into haploid males which proceed to mate with the females and fertilize their haploid eggs. The fertilized eggs are laid at the bottom of the pond where they survive the winter to continue the same cycle of events the following year.



21. What is the advantage of reproducing asexually as is the case with water fleas during the summer?

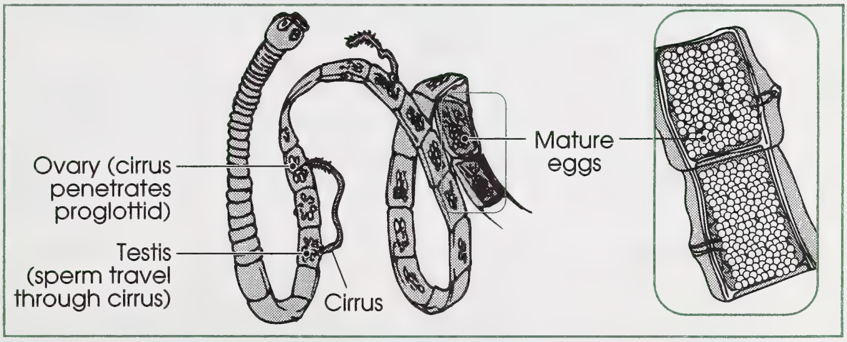


Check your answers by turning to the Appendix, Section 2: Activity 4.

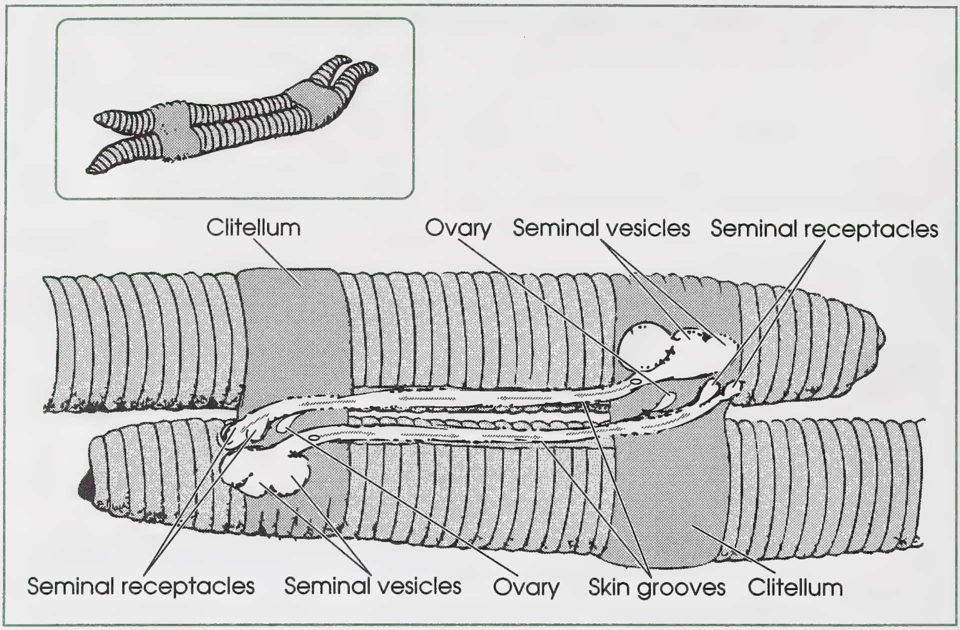
hermaphroditic – condition of having both male and female sex organs in the same organism

Cross-fertilization is also predominant in the animal kingdom. However, some organisms live in isolation and rarely meet with individuals of the opposite sex. They may be **hermaphroditic** species, which have both male and female sex organs and can self-fertilize. This ensures that they can reproduce if another individual is not around.

Tapeworms are hermaphroditic. Cross-fertilization will occur if two or more worms live in the same intestine but tapeworms will self-fertilize when no other worms are available.


Ovary (cirrus penetrates proglottid)
Testis (sperm travel through cirrus)
Cirrus
Mature eggs

Earthworms are also hermaphroditic and usually cross-fertilize. Notice the difference between self-fertilization in tapeworms in the previous diagram and cross-fertilization in earthworms as shown in the following diagram. In earthworm cross-fertilization, sperm is transferred from the seminal vesicles of each worm to the seminal receptacles of the other worm.



Although many organisms rely on asexual reproduction for rapid population growth, they will resort to sexual reproduction at some point in order to increase variations among the individuals making up the population. Such a pattern occurs in all the kingdoms of organisms increasing the chances of survival of the species over time. Simple organisms tend to be haploid; more complex species are diploid. Reproduction involves both meiosis and mitosis, with meiosis reducing chromosome numbers to the haploid and mitosis producing more cells of the same kinds.

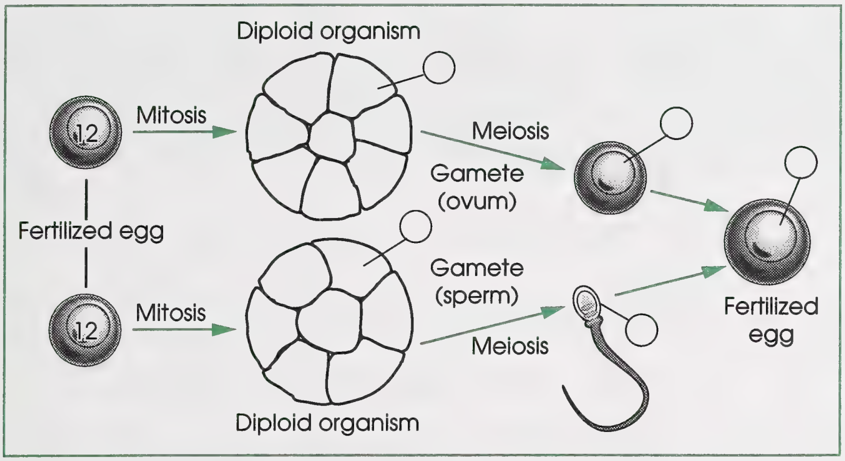
Follow-up Activities

If you had difficulty understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

When diploid organisms reproduce sexually they must produce sex cells through meiosis to ensure that the offspring inherit the appropriate number of chromosomes. Sex cells must only carry one set of chromosomes, because when fertilization occurs two sets are recombined in the zygote to restore the diploid condition. Meiosis reduces the chromosome number of somatic cells from two sets to one set in the cells to be used for reproduction. In this way the chromosome count from generation to generation remains the same in a species.

1. Use this information to predict the number of chromosomes in the cells in this diagram.



The following questions are intended to assist you in developing a better understanding of the concepts covered in this section or to reinforce them.

2. Find an appropriate term or phrase to match each of the following definitions. Try to complete the list of terms first without help. Then use your notes and text for any terms left.

    a. a form of cell division that reduces the chromosome count from two sets to one

    b. female sex cell

    c. chromosomes similar in size, shape, and traits that their genes affect are called

    d. the stage of a cell cycle characterized by cellular growth and normal biochemical activity

    e. a pair of homologous chromosomes with their duplicates forming a group of four chromatids

    f. the exchange of segments of homologous chromosomes during the tetrad stage

    g. the process of making exact copies of chromosomes

    h. the phase of meiosis during which the homologous chromosomes separate

    i. a cell with one of each kind of chromosome rather than two

    j. division of the cytoplasm

k. meiosis in the testes

l. diploid cell that gives rise to an egg cell

m. the sex chromosomes

n. the failure to separate homologous chromosomes

o. body cells

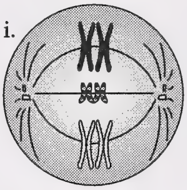
p. the haploid stage of a plant's life cycle that produces gametes

q. the shift from a diploid, spore-producing stage to a haploid, gamete-producing stage

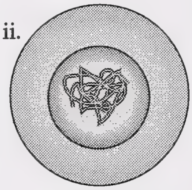
r. condition of having both male and female sex organs

3. a. Identify the phases of meiosis shown.

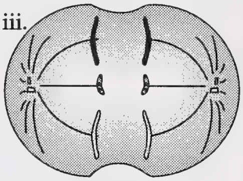
i.



ii.



iii.



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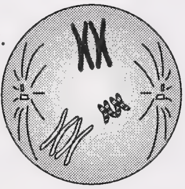
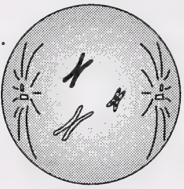
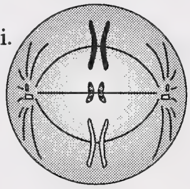


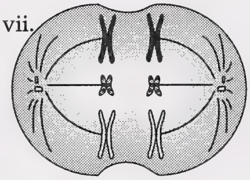
v.



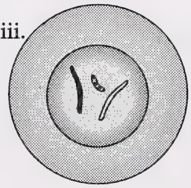
vi.



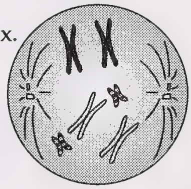
vii.



viii.



ix.



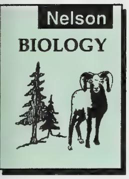
b. Starting with cell ii., list the numbers of the cells in the most likely order of meiosis.

4. Draw a diagram of the chromosomes of the original mother cell that would give rise to the cells in question 3.

5. A cell has a diploid number of fifty-six. Use this chromosome number where applicable in completing the table comparing mitosis and meiosis.

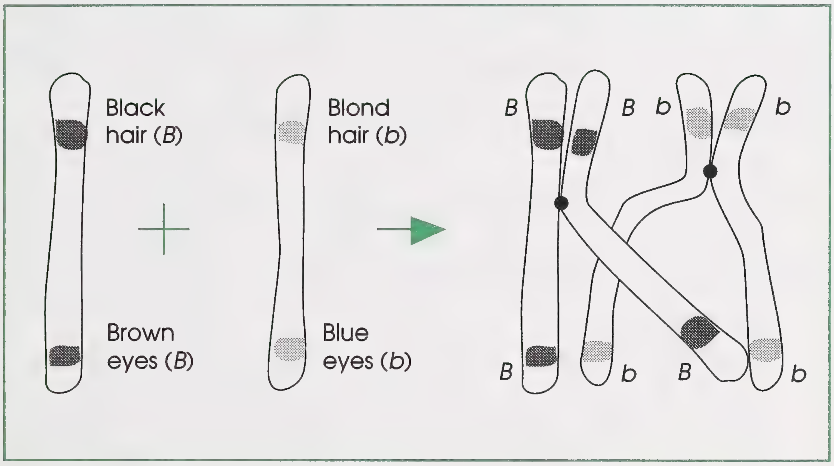
Comparison of Mitosis and Meiosis

Type of Cell Division	Number of Cells Produced		Number of Chromosomes in Daughter Cells	Place of Occurrence in the Body
	Male	Female		
Mitosis				
Meiosis				



Crossing-over occurs when homologous chromosomes exchange sections. Carefully study Figure 19.4 and 19.5 on page 450 in your text. Although you'll study more about genes and their traits in Module 5, you should be able to answer this next question now.

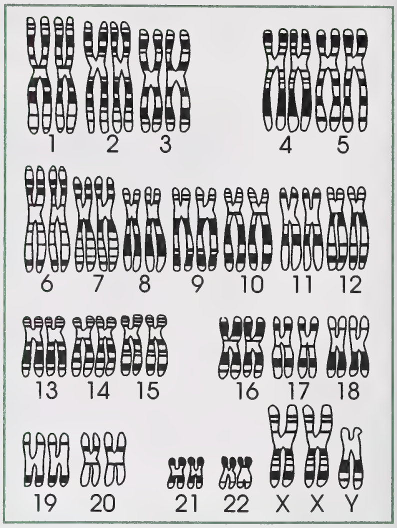
6. Black hair and brown eyes often go together. Assume the genes for these two traits are located on one chromosome. Blond hair and blue eyes also seem to go together. Assume that the genes for these two features are located on the other homologous chromosome as shown in the sketch.



a. If crossing-over occurs between these two homologues during prophase I, what would be the new combinations of genes that would result?

b. What is the function of crossing-over in reproduction?

As a natural and frequent occurrence, crossing-over should not be considered a genetic mutation. It only creates new combinations of traits that already exist. Later these traits may travel together in a gamete.



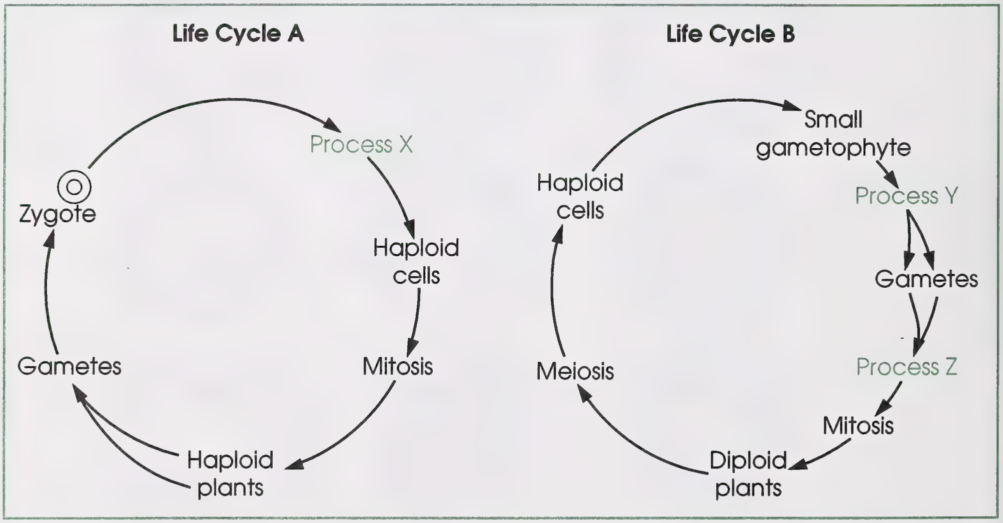
Use the illustration on the right to answer the next set of questions about nondisjunction.

7. a. What do you call a photograph of an individual's complete set of chromosomes, with homologues generally rearranged and grouped together?

   b. Identify the genetic anomoly (abnormality) of the individual from whom these chromosomes were taken. Explain how this would have come about.

   c. What is the sex of the individual?

Study the two life cycles of plants and answer the questions that follow.



8. a. Identify processes X, Y, and Z.

   b. Which cell division, mitosis or meiosis, gives rise to gametes in both life cycles? Why must this be the case?

   c. Which cycle is more representative of the higher plants? Explain.

   d. Which stage is dominant in Life Cycle A, the gametophyte or sporophyte?

e. Which life cycle shows a true alternation of generation? Why?

f. If the diploid plants in Life Cycle B are flowering plants, what would be the structures containing the haploid cells produced by meiosis?

Check your answers by turning to the Appendix, Section 2: Extra Help.

Enrichment

1. In February of 1960, a one-year-old boy was brought to a pediatric clinic at Orebro, Sweden, for a medical checkup and was found to have sixty-nine chromosomes in the nuclei of his skin cells. His karyotype was three complete sets of autosomes and XXY. How would you explain this chromosome aberration?

2. The term *haploid* means one set of chromosomes, diploid means two, triploid means three sets of chromosomes, and so on. Visit a library and research the genetics of plant breeding in order to answer the following questions.

   a. What is polyploidy and how is it artificially induced in plants?

   b. Identify some polyploid varieties of plants that have great commercial value.

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3. Read page 460 in your text to learn about an unfortunate case of science and society coming together.

   a. What kind of nondisjunction could result in the XYY condition?

   b. What factor has now replaced the XYY condition as more likely determining criminal behaviour?

4. Construct a human karyotype from Plate B in the Appendix. Arrange the chromosomes in pairs by comparing them to a normal human karyotype as on page 459 in your text. Determine the sex of the karyotype and any other characteristics.

Check your answers by turning to the Appendix, Section 2: Enrichment.

Conclusion

Sexual reproduction generates variability among members of a species and is critical to adaptation of species to changing environmental conditions. Each time an egg and sperm unite, a new combination of genes is produced giving rise to an individual that is unique. The cells needed for sexual reproduction are haploid, carrying only one set of chromosomes. When fertilization occurs, the diploid number, characteristic of the species, is restored. Production of haploid gametes occurs through meiosis in the testes and ovaries. This process involves a reduction division followed by a mitotic division. Oogenesis produces one functional egg; spermatogenesis produces four functional sperm cells. Abnormalities in the process can lead to chromosome anomolies with serious defects. Many organisms alternate between asexual and sexual reproduction producing recognizable reproductive patterns.

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Section 2 Assignment: Sex Cell Production

Review the Evaluation information found in the introductory pages of this module.

Response Page Setup

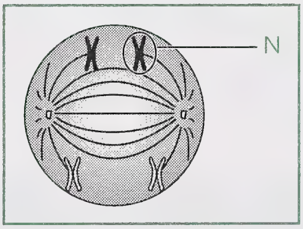
It is important to number and clearly identify each page with the following information at the top:

Biology 30 – Module 4 Section 2 Assignment Page # Name and ID#

Be sure to write legibly. Leave a wide left margin and number all of your pages.

Carefully read each of the following multiple choice questions and decide which of the choices **best** completes the statement or answers the question. Each question is worth 1 mark.

Use the following diagram to answer questions 1 to 4.



1. The previous diagram illustrates

   A. metaphase during meiotic cell division
   B. metaphase during mitotic cell division
   C. anaphase during meiotic cell division
   D. anaphase during mitotic cell division

2. This type of cell division would occur in

   A. onion root tissue
   B. human body cell
   C. any living tissue
   D. plant reproductive tissue

3. Structure N represents

   A. chromosome
   B. centriole
   C. centromere
   D. chromatid

4. If there were twenty-three homologous pairs of chromosomes in the body cell of an organism, how many chromosomes will there be in the final cells produced by meiosis?

   A. 12
   B. 23
   C. 46
   D. 96

5. In organisms such as humans with X and Y sex chromosomes, the gender of offspring will be determined by

   A. both male and female parents
   B. only the female parent
   C. chance rather than either parent
   D. only the male parent

Questions 6 to 8 are based on the following key to cell division processes. Use the key to classify each of the following statements.

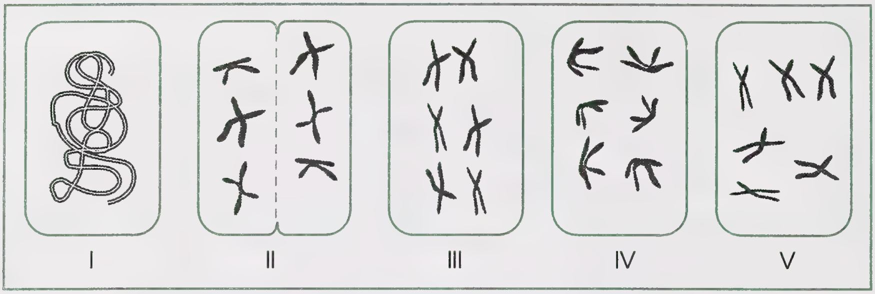
Key: A. mitosis
B. meiosis
C. both mitosis and meiosis
D. neither mitosis nor meiosis

6. This type of division prevents an increase in number of chromosomes from generation to generation.

7. Diploid cells are formed.

8. Each chromosome duplicates itself.

Use the following information to answer question 9.



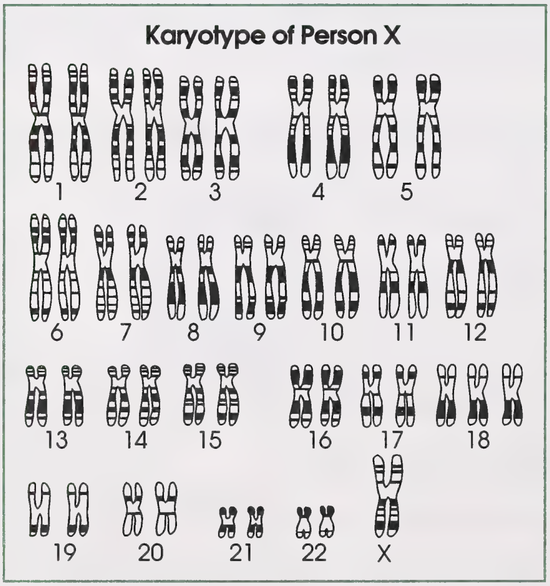
9. The order in which these cell patterns would appear during cell division is

A. I, III, IV, V, II
B. V, III, I, II, IV
C. I, V, III, IV, II
D. III, I, V, II, IV

10. Which cell in question 9 could first indicate that nondisjunction had occurred?

A. II
B. III
C. IV
D. V

Use the following information to answer question 11.



Science Skills

☐ A. Initiating
☐ B. Collecting
☐ C. Organizing
☑ D. Analysing
☑ E. Synthesizing
☐ F. Evaluating

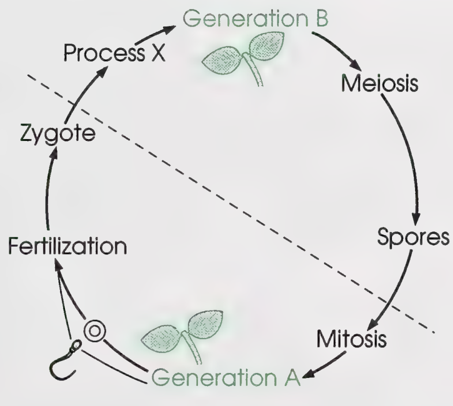
11. Compose a description of this individual including sex, chromosome numbers, all abnormalities, and an explanation of how this karyotype was formed. **(6 marks)**

Reproduce the science skills assessment box after your response to this question. Remember to indicate your evaluation of your skill level for each identified science skill. Be sure to include the spaces for teacher assessment.

Self: A. ☐	B. ☐	C. ☐	D. ☐	E. ☐	F. ☐
Teacher: A. ☐	B. ☐	C. ☐	D. ☐	E. ☐	F. ☐

Use the following diagram to answer question 12.

Life Cycle of a Plant Showing Alternation of Generation



12. a. Which plant undergoes sexual reproduction? **(1 mark)**

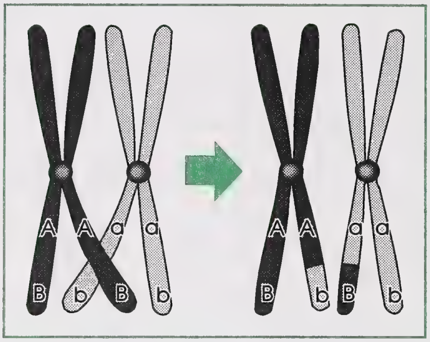
    b. Explain the sporophyte phase of the life cycle. **(2 marks)**

    c. If these two plants evolved into a single organism such as an apple tree, which plant (A or B) would become the apples? Briefly explain your choice. **(2 marks)**

13. a. Using a cell with a chromosome number of four, show how metaphase of mitosis differs from metaphase I of meiosis. Chapters 18 and 19 in your text have examples of cell diagrams. **(2 marks)**

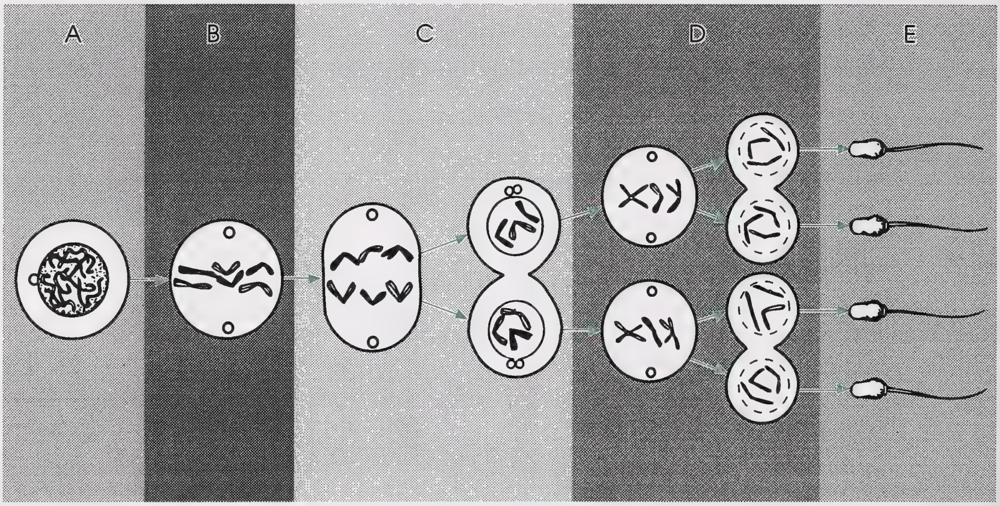
    b. Explain the significance of this difference. **(1 mark)**

Use the following diagram to answer question 14.



14. What purpose does the process seen in the previous diagram serve? **(1 mark)**

Use the following diagram to answer question 15.



15. a. Indicate the section of the meiotic process where oogenesis first shows a difference from spermatogenesis. Explain the significance of this difference. **(2 marks)**

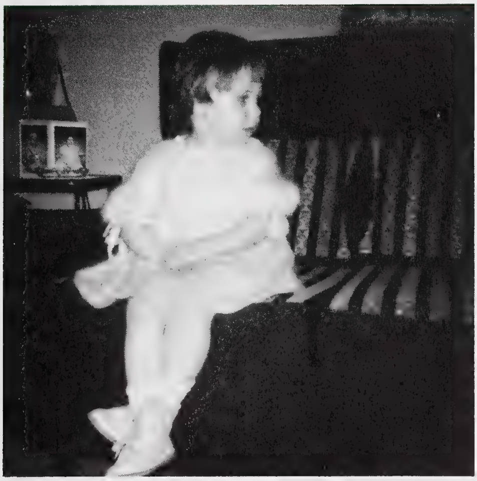
    b. If the genetic composition of the gametes is fifteen chromosomes, what is the number in the cell in Section A? **(1 mark)**

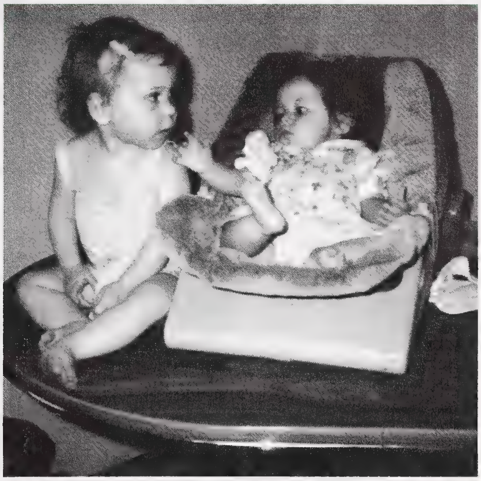
    c. Which section shows separation of homologous chromosomes? **(1 mark)**

    d. Which section shows separation of chromatids? **(1 mark)**

SECTION 3

Classical Genetics





While looking through an album of family photos, six-year-old Ashley suddenly pointed to an old photo and said "Hey, that's me!" Her mother laughed and explained "No, that's me when I was two years old." Ashley was perplexed. The resemblance was very strong. Obviously a strong pattern of inheritance existed.

Genetics is the study of how characteristics are passed from one generation to the next. In this section you will study the patterns of inheritance from simple to more complex. You'll also learn that along with definite patterns, chance and probability play a role in heredity.

Imagine looking at a photo of yourself that was taken long before you even existed. No, this isn't a scene from *Back to the Future*. It is a near possibility in family albums. Similarities between parents and children can be amazingly strong when photos of individuals at the same age are compared. The photo on the left is the mother of one of the children on the right. Can you tell which one? Based on your knowledge of meiosis and mitosis, you should be able to appreciate that the genetic material you now carry existed before you were born, and so did some of your characteristics.

ACTIVITY

1 Single-Trait Inheritance

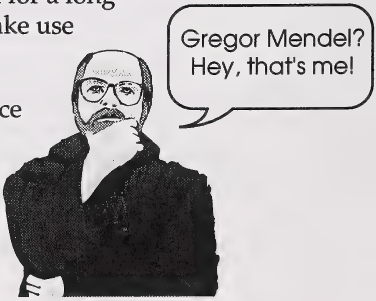
COURTESY OF KATHLEEN MERRILLS

Family resemblance is often most obvious in eye colour, hair colour, shape of the nose, and other single characteristics or traits. Are these traits inherited singly or in groups? Which ones might be inherited together?

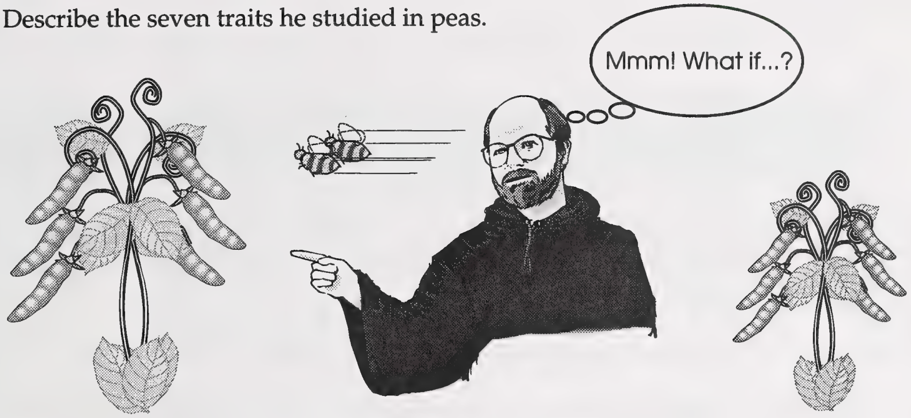
In this activity you'll discover how genes for basic characteristics are passed from parents to offspring. You'll also encounter an interesting historical character who will help guide you in your studies of genetics.

Read pages 468 to 470 of your text to get a historical perspective of genetics.

1. The idea that biological traits were inherited existed for a long time. How did the Chinese and the Babylonians make use of this idea?
2. Where did Aristotle believe the factors for inheritance were located in the body?
3. What contribution did Gregor Mendel make to man's understanding of heredity?
4. Why did Mendel choose to study peas in his genetics experiments?


Gregor Mendel? Hey, that's me!

5. Describe the seven traits he studied in peas.

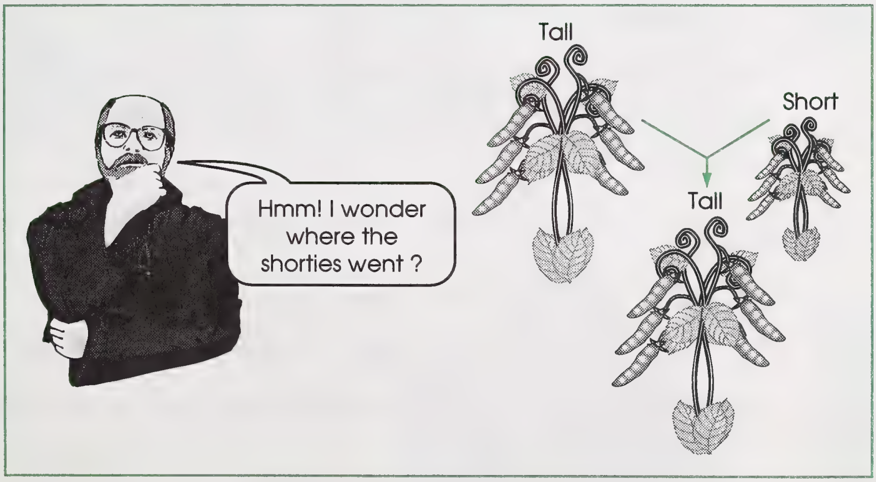


Mendel noticed that some plants in his garden were tall and others were short. He followed several generations to ensure that he had pure breeding lines of tall and short plants. Now he was ready for the true experiment. He cross-pollinated pure-breeding tall plants with the pure-breeding short plants. Figure 20.5 on page 470 in your text shows how this is done.

6. Predict the size of the offspring plants.

7. What prediction do you think Mendel made?

When Mendel planted the seeds produced by the plants of the initial cross, he got unexpected results; all of the plants were tall. None of the offspring was intermediate in size and not one was short. Since none of the plants were of intermediate size as he expected, that meant there was no blending of these contrasting features.

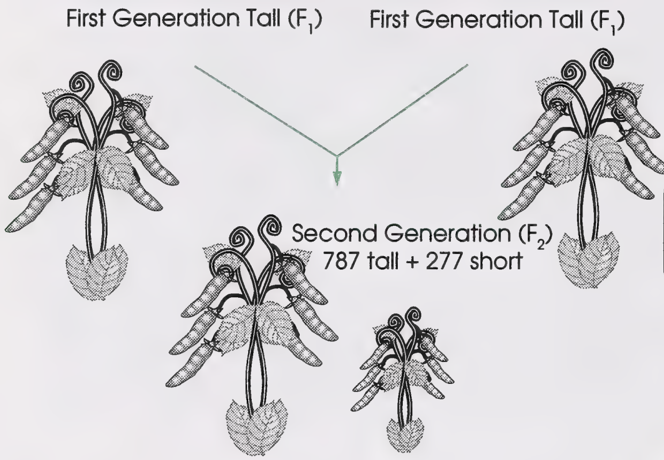

Tall
Short
Tall
Hmm! I wonder where the shorties went ?

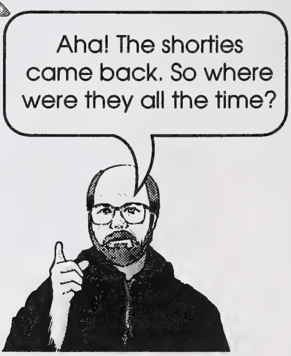
8. If you were Mendel what would you do next to answer the question he is asking himself?

Check your answers by turning to the Appendix, Section 3: Activity 1.

F_1 – first filial generation that inherits factors from the original parents
$P_1 \times P_1 \rightarrow F_1$

Mendel suspected that the answer might come from crossing first generation (F_1) plants with each other. So that's what he did. Surprisingly, short-stem plants reappeared in the second generation.


First Generation Tall (F_1)
First Generation Tall (F_1)
Second Generation (F_2)
787 tall + 277 short


Aha! The shorties came back. So where were they all the time?

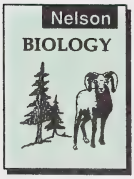
F_2 – second filial generation that inherits factors from the F_1 generation
$F_1 \times F_1 \rightarrow F_2$

9. What is the ratio (in whole numbers) of tall plants to short plants in the F_2 generation?

factor – a gene that produces a specific physical feature

Because the tall and short stems remained distinct and did not blend in hydrids, Mendel concluded that there must be a factor for tall and a factor for short. One factor was passed on by each parent to each offspring through the gametes. Today these factors are called genes.

Read page 471 of your text for information about Mendel's experiments and his laws of heredity.



10. How does a dominant factor differ from a recessive factor?

11. Explain the principle of dominance and apply it to stem length in peas.

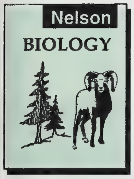
Mendel called plants hybrids if they were the offspring of pure-breeding parents showing contrasting features.

12. How does your text define the term *hybrid*?

Mendel made similar crosses with peas using other traits where two contrasting varieties existed. These are given in the following table.

Results of Mendel's Crosses Where Parents Differed Only in One Trait

Trait of Parent	Trait of F_1's
round × wrinkled seeds	
yellow × green seeds	
purple × white flowers	
green × yellow pods	
inflated × constricted pods	
axial × terminal flowers	



13. Find out which contrasting feature listed in the table is dominant and which is recessive by referring to page 470 of your text; then fill in the trait that would appear in the F_1's for each cross on this table.

14. How many factors are there for length of stem and for each of the other traits Mendel studied?

15. Do the results give a clear indication of the number of factors each parent passes on to each offspring for any one trait?

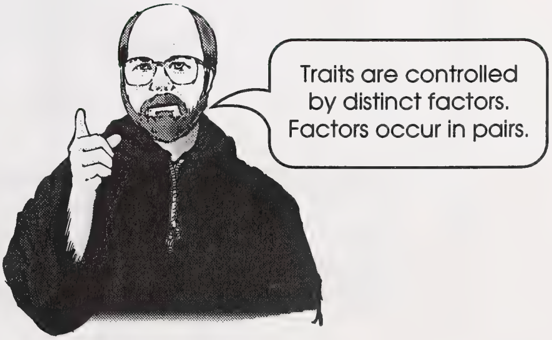
16. What evidence is there for Mendel's principle of dominance?

Check your answers by turning to the Appendix, Section 3: Activity 1.

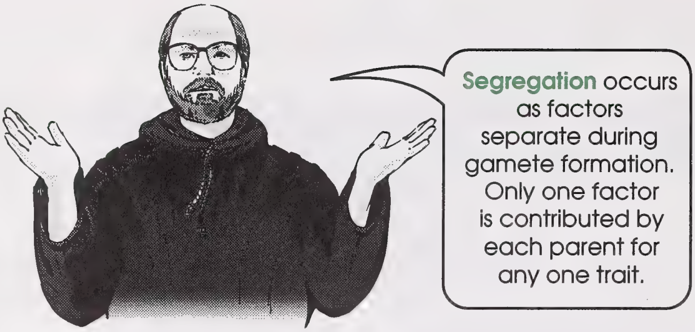
ACTIVITY

2 Monohybrid Crosses

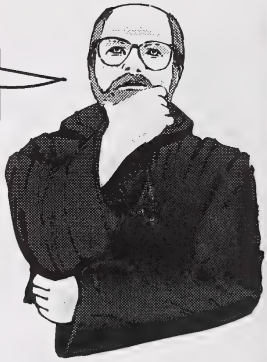
Based on Mendel's results with peas, you can make some generalizations and conclusions about basic laws of genetics. You have probably come to some of the same conclusions and made similar generalizations as Mendel.

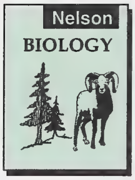

Traits are controlled by distinct factors. Factors occur in pairs.

segregation – the separation of the two factors for a trait during gamete formation so that each gamete receives only one factor


Segregation occurs as factors separate during gamete formation. Only one factor is contributed by each parent for any one trait.

1. Mendel could not explain why factors came in pairs. What simple explanation is there to answer this question?

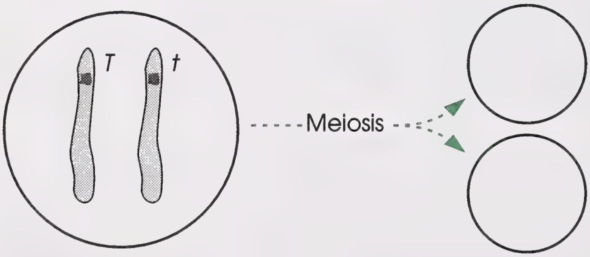

Why should there be two factors when one will do the job?



2. Check page 473 of your text to find the name given to genes that produce a variation of the same trait. Mendel referred to them as contrasting factors.

Mendel did not know how the factors segregated, but you do because you have the understanding of meiosis. Since homologous chromosomes are separated by this process, so are the pairs of alleles.

3. Show how the factors *T* and *t* segregate through meiosis. You may have to go back to Section 2 of this module and to pages 450 to 451 of your text to review meiosis before you attempt this question. Start with the homologous chromosomes shown in the following sketch and draw the chromosomes in the gamete cells produced.



The original cross between tall plants and short plants will become more meaningful as you apply the generalizations learned so far. Alleles will be symbolized with the letters *T* for tall and *t* for short stem. The purebred tall plant then will be represented by *TT* and the purebred short plant by *tt* because alleles occur in pairs. For convenience, two new terms *genotype* and *phenotype* must be introduced here before you can continue.

Nelson BIOLOGY

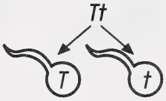
4. a. Differentiate between the terms *genotype* and *phenotype* by referring to pages 472 and 473 of your text. Apply these terms to *TT* and tall.

   b. Explain how two different genotypes could produce the same phenotype. To do this you may need to review the terms homozygous and heterozygous on page 473 in your text.

5. Place the appropriate term in the space provided for each picture. Use the following words: *genotype, phenotype, segregation.*

Blue eyes

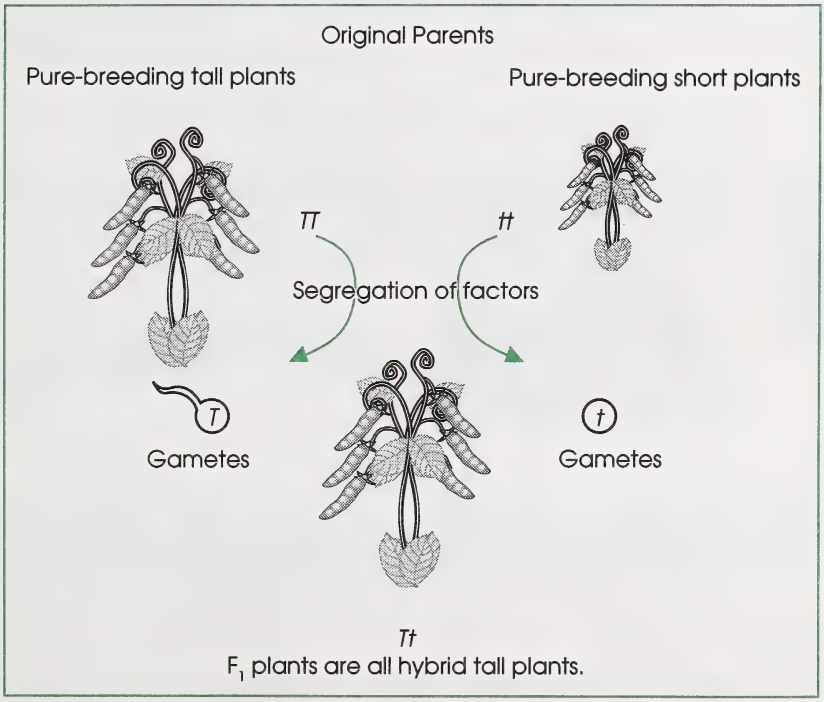
bb



a. ____________________ b. ____________________ c. ____________________

Check your answers by turning to the Appendix, Section 3: Activity 2.

The original cross can now be summarized as follows:

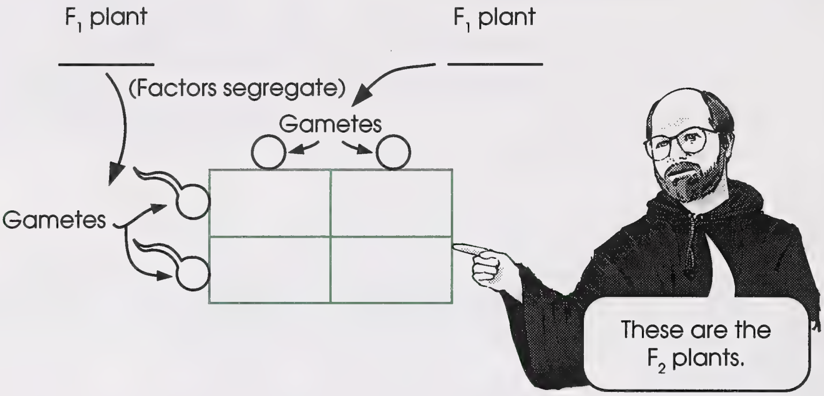


F_1 plants are all hybrid tall plants.

Tall and short are the only possible phenotypes for pea plant stem length.

6. Using the same method, two F_1 hybrid tall plants can now be crossed as shown in the following chart.

   a. Fill in the genotype of the parents, the factor in the gametes produced by each parent, and the genotypes possible in each of the offspring.



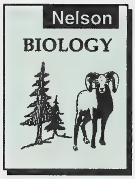
Science Skills

☐ A. Initiating
☐ B. Collecting
☐ C. Organizing
☑ D. Analysing
☑ E. Synthesizing
☐ F. Evaluating

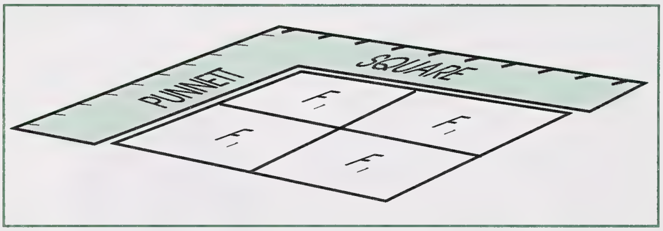
   b. What proportion of the F_2 offspring are short?

   c. What percentage of the offspring are pure-breeding tall?

   d. Give the genotype of the short plants.



The square previously used is called a Punnett square. It is commonly used by modern geneticists as a convenience to show the possible genotypes in offspring. Check Figures 20.8 to 20.11 on pages 473 to 475 in your text for more examples.



Based on the proportion of genotypes and phenotypes shown in the Punnett square it is possible to predict the percentage of the various types of offspring you would get in such a cross.

Mendel crossed hybrids (F_1's) for all seven traits he studied in peas. The following table shows the actual results of these crosses.

7. Calculate the ratio of dominant to recessive traits in the F_2's to the second decimal place on the following table. The first one is done for you.

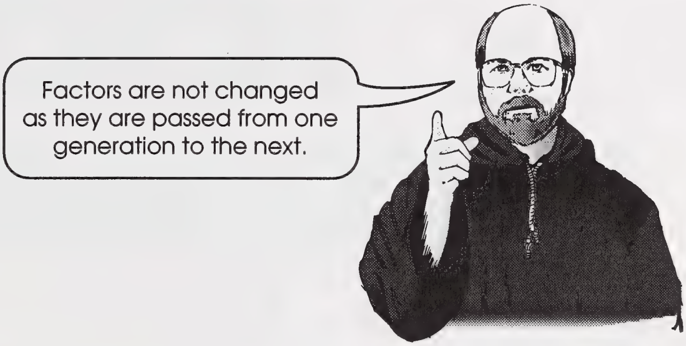
Results of Mendel's Crosses Where Parents Differed Only in One Trait

Parent Phenotypes	F_1	F_2	F_2 Ratio
tall × short	all tall	787 tall; 277 short	2.84:1
round × wrinkled seeds	all round	5474 round; 1850 wrinkled	
yellow × green seeds	all yellow	6022 yellow; 2001 green	
purple × white flowers	all purple	705 purple; 224 white	
green × yellow pods	all green	428 green; 152 yellow	
inflated × constricted pods	all inflated	882 inflated; 299 constricted	
axial × terminal flowers	all axial	651 axial; 207 terminal	

Remember that F_2's are produced by crossing F_1's with F_1's.

8. a. Is there any blending of contrasting features in any of the cases with which Mendel experimented?

   b. What is the general ratio of the dominant trait to the recessive trait in whole numbers in every case of the F_2 plants?


Factors are not changed as they are passed from one generation to the next.

Check your answers by turning to the Appendix, Section 3: Activity 2.

Nelson
BIOLOGY

Carefully read the section entitled Single-Trait Inheritance on pages 473 and 474 of your textbook. Note the definitions of key terms. You must become fluent in the use of all the terms introduced so far. There are more terms to come.

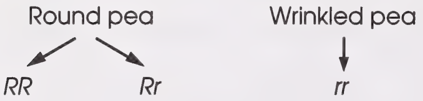
So far you have been analysing Mendel's crosses where he was investigating the inheritance of only one trait at a time.

9. What are single-trait crosses called?

10. Explain the difference between a heterozygous and homozygous round seed pea plant in terms of phenotype and genotype.

In peas, round coat is dominant to wrinkled coat. A pea plant can either be homozygous or heterozygous for round seed shape, but it always must be homozygous for wrinkled seed shape (recessive trait). This can be shown using *R* as the factor representing round and *r* representing the factor for wrinkled.

11. In the following illustration label each as heterozygous or homozygous.



a. ________ b. ________ c. ________

12. Why can't you have a heterozygous wrinkled seed plant?

13. Give the ratio of dominant to recessive features expected in each of the crosses shown in the table. Express the ratio in percentage. The first one is done for you.

Description of Parent 1 Genotype	Description of Parent 2 Genotype	Phenotypic Ratio of Dominant to Recessive in Offspring
Homozygous dominant	Homozygous recessive	100% to 0%
a. Heterozygous	Homozygous recessive	
b. Heterozygous	Heterozygous	
c. Homozygous recessive	Homozygous recessive	

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☐ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Check your answers by turning to the Appendix, Section 3: Activity 2.

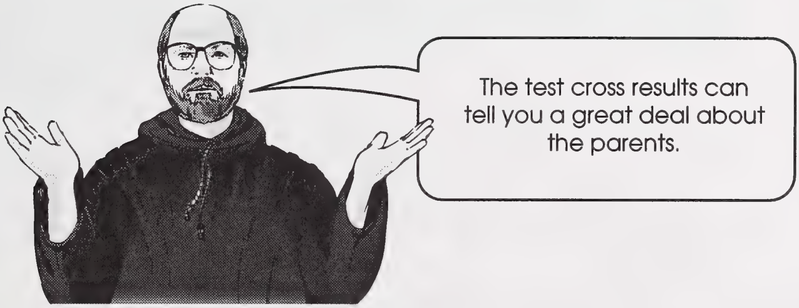
Nelson BIOLOGY

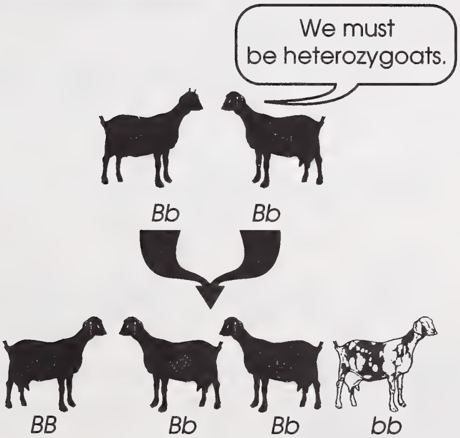
Suppose you were given a tall pea plant and told to determine whether it was homozygous tall or heterozygous tall. How could you do this? Read the Test Cross section on page 475 of your text to find the answer to this question. Read this section carefully before proceeding.

14. The following table summarizes the test cross results where the genotype of the tall plant needs to be determined. Fill in the blanks to complete the table.

Tall Plant (homozygous or heterozygous)		**Short Plant (homozygous recessive)**	**Genotype of F_1's**	**Phenotype of F_1's**
TT: ____________	crossed with	____________	All are ________.	All are ________.
Tt: ____________	crossed with	____________	50% ________ 50% *tt*	50% tall 50% ________

You can see that if in a test cross the recessive feature does not appear in any of the offspring, then the individual in question must be homozygous (pure breeding) for its dominant trait. If the recessive feature appears in any of the offspring, then the parent with the dominant feature must be heterozygous (a hybrid).


The test cross results can tell you a great deal about the parents.



Now that you are familiar with the principles of Mendelian inheritance, you're ready to apply what you have learned to a genetics problem.

Science Skills

☐ A. Initiating
☐ B. Collecting
☐ C. Organizing
☑ D. Analysing
☐ E. Synthesizing
☐ F. Evaluating

15. In fowl, silky feathers are recessive to normal feathers. Show the results of a cross between a silky feathered bird and a heterozygous normal bird. Using *N* for normal feathers and *n* for silky, give the following:

    a. genotypes of the parents

    b. genotypes and phenotypes of the offspring

    c. phenotypic ratio of the F_1's

    d. If several heterozygous birds are crossed to produce 200 birds in the F_1 generation, calculate the theoretical number of F_1's that would be homozygous normal and the number that would be silky feathered.

Check your answers by turning to the Appendix, Section 3: Activity 2.

You should remember that in Mendel's time, little was known about sperm and egg cells although it was understood that both were needed for reproduction. He knew that pollen grains carried the sperm and the pistil of the flower contained the egg. He did not know that they carried genetic material called genes nor did he understand how these cells were formed. This lack of such information makes his work that much more remarkable.

You have studied the inheritance of one trait where a pair of contrasting genes produces two different forms. Now, what would happen if you were to follow the inheritance of two such traits at the same time?

ACTIVITY

3 Dihybrid Crosses

Jason raised two varieties of purebred guinea pigs for commercial purposes. One variety was black and short-haired, and the other was white and long-haired.

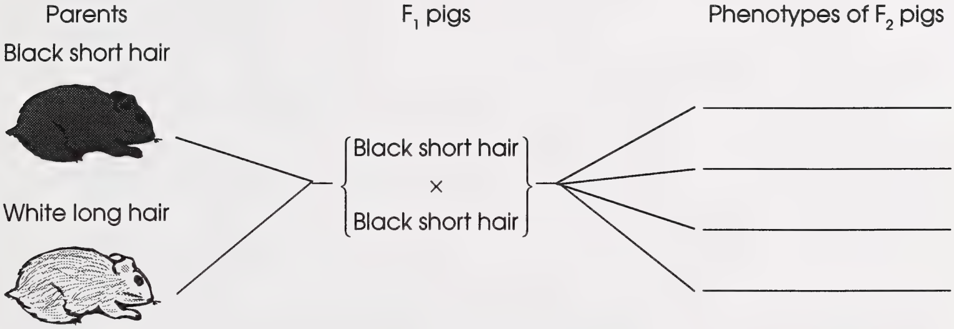
He was interested in maintaining the two pure strains so he kept them in separate pens to prevent interbreeding. Jason's friend Derek wondered what the offspring would look like if the two types were crossed.

One day a black, short-haired male and a white, long-haired female escaped from their pens and spent several hours together. Jason was not certain that mating took place but he didn't want to take a chance so he gave these animals to Derek. Derek finally had his chance to find out what happened when the two types were crossed.

1. If Derek mates the two guinea pigs what would he learn about the inheritance of coat colour and hair type in this animal? Explain.

Derek bred these two animals several times and found that all the young were black with short hair. Derek released the young in a large pen where they proceeded to interbreed and produce offspring. The second-generation guinea pigs showed four different phenotypes.

2. What four phenotypes would he have gotten in the F_2 generation? Remember that a phenotype will include coat colour and hair length.

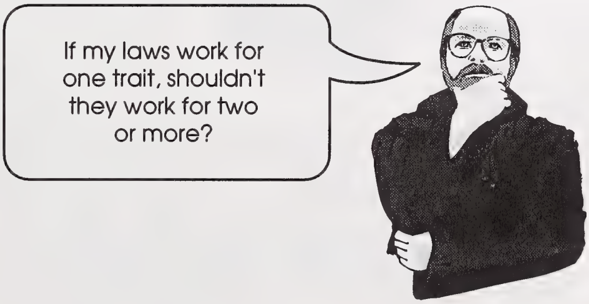


How could these results be explained? What law of genetics is being demonstrated here?

Nelson BIOLOGY

Read the section entitled Dihybrid Crosses on pages 480 and 481 of your text to become familiar with Mendel's experiments involving the inheritance of two traits at the same time.

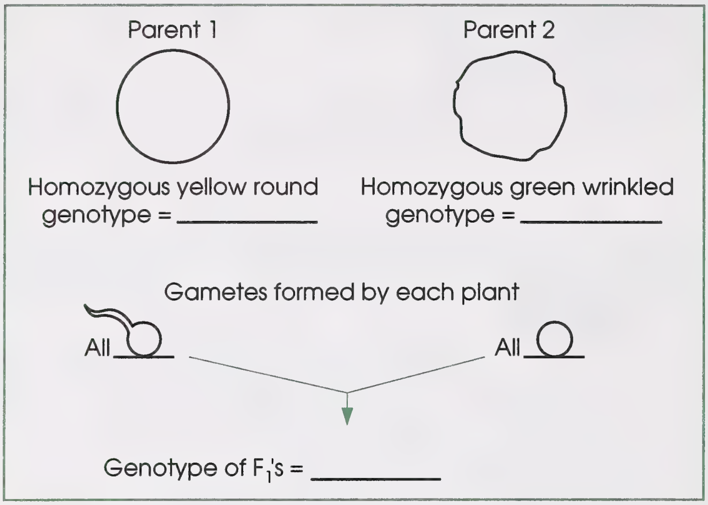
3. How is a dihybrid cross different from a monohybrid cross?


If my laws work for one trait, shouldn't they work for two or more?

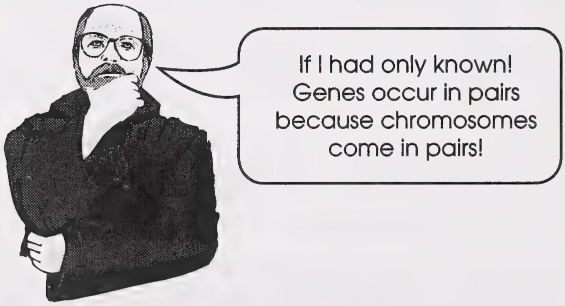
Mendel performed dihybrid crosses in peas to determine if the inheritance of one trait had any influence on the inheritance of another trait.

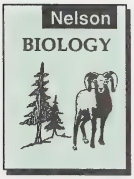
He crossed a pea plant that was pure-breeding (homozygous) for both yellow seed colour and round seed coat with another pea plant that was homozygous for both green pea colour and wrinkled seed coat. Remember that round coat *R* is dominant over wrinkled *r*, and yellow colour *Y* is dominant over green *y*.

4. Fill in the genotypes for the individuals involved in this cross.


Parent 1
Parent 2
Homozygous yellow round genotype = ____________
Homozygous green wrinkled genotype = ____________
Gametes formed by each plant
All ______
All ______
Genotype of F_1's = ____________

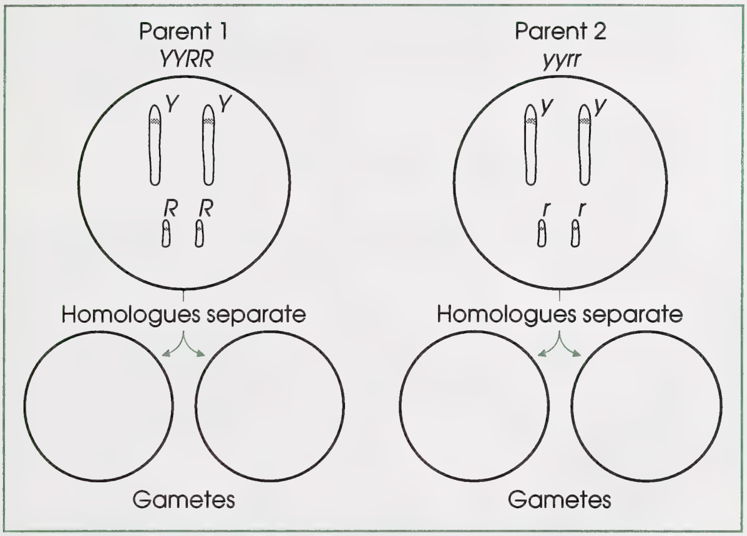
5. What is the phenotype of the F_1 plants produced from this cross?


If I had only known! Genes occur in pairs because chromosomes come in pairs!



To better understand how two pairs of genes segregate during egg and sperm cell formation, you must go back to meiosis. To refresh your memory of this process turn to pages 450 and 451 of the textbook and study the diagrams.

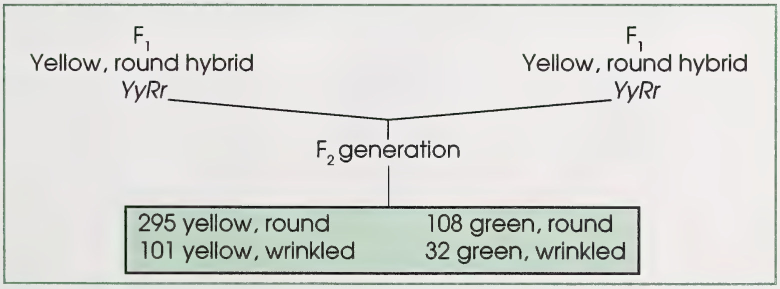
6. Complete the following diagram by drawing in the chromosomes and the genes that would be found in gametes from *YYRR* and *yyrr* parent plants. Notice that the genes for pea colour are on one pair of homologous chromosomes and the genes for shape of seed coat are on another pair. For each parent, take the cell with the two pairs of chromosomes through a simplified meiotic division to see how the two pairs of genes separate independently of each other. You can ignore replication of chromosomes.



Check your answers by turning to the Appendix, Section 3: Activity 3.

Mendel found that factors segregate for each of the two traits as he had seen in monohybrid crosses. Since the two traits are being inherited together, every gamete has one factor for seed colour (*Y* or *y*) and one factor for smoothness of coat (*R* or *r*).

Now, what would happen if you were to cross F_1 plants with each other? Mendel performed this cross and got these results.



7. How many different phenotypes did he get? Is this consistent with the number Derek got with his guinea pigs?

8. Determine the following phenotypic ratio of the F_2 generation by reducing the numbers of the four phenotypes given to their lowest common denominator; i.e., divide by thirty-two. Place the ratios in the following table.

   a. both dominant traits (yellow, round)

   b. one dominant, one recessive (green, round)

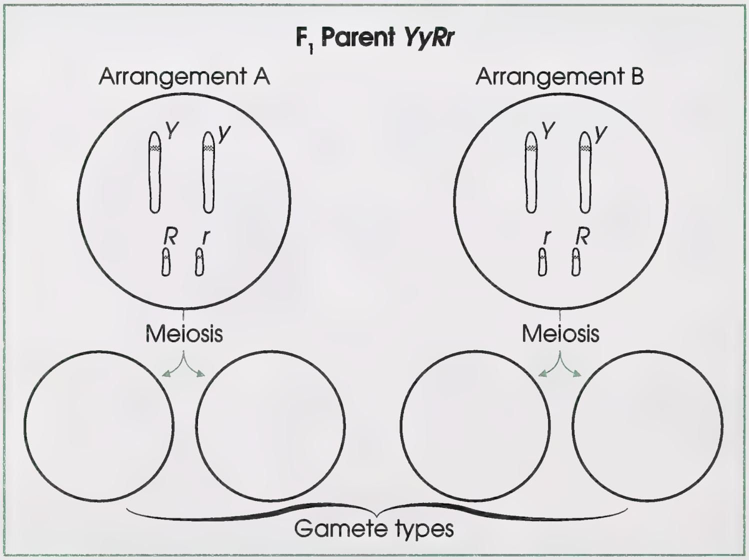
   c. one recessive, one dominant (yellow, wrinkled)

   d. both recessive (green, wrinkled)

The phenotypic ratio you see here is the typical **9:3:3:1** ratio you get whenever you cross two dihybrids.

Figure 20.19 on page 481 of your text shows the possible gametes the F_1 parents produce. Notice that each *YyRr* parent produces four kinds of gametes in equal proportions because the two pairs of chromosomes can align on the metaphase plate in two different ways during meiosis. Figure 20.20 shows all possible combinations of these gametes in the F_2 generation.

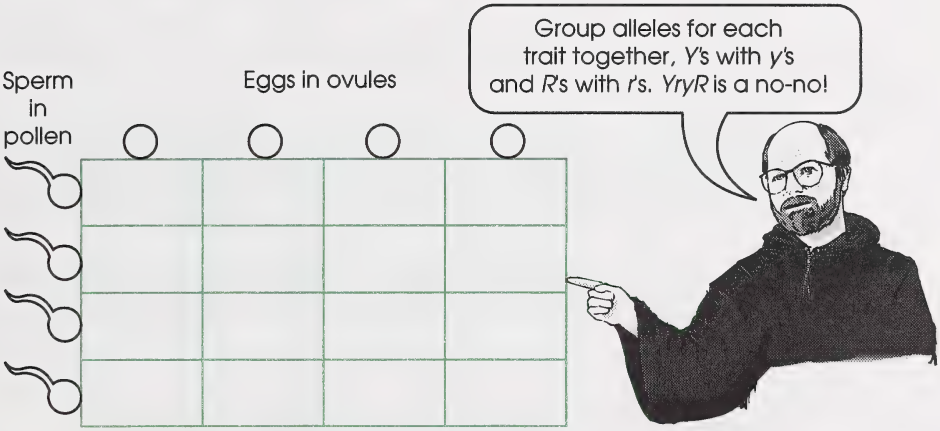
9. Half the time the chromosomes align as shown in Arrangement A and the other half as in Arrangement B. Fill in the chromosomes and the respective alleles in each gamete produced.



There are four different kinds of gametes possible then, all produced in equal proportions by each F_1 parent when heterogyzous for both traits. This is true because the segregation of genes for pea colour is not influenced by the segregation of genes for smoothness of seed coat. This observation by Mendel led to his second law called the Law of Independent Assortment. This law is an extension of his first law, the Law of Segregation.

10. State this law in your own words.

11. Place the four kinds of gametes for each F_1 parent in question 9 on the Punnett square and fill in the possible genotypes.


Group alleles for each trait together, *Y*'s with *y*'s and *R*'s with *r*'s. *YryR* is a no-no!
Sperm in pollen
Eggs in ovules

Nelson
BIOLOGY

12. Answer the next three questions using the Punnett square in Figure 20.20 found on page 481 of your textbook.
    a. List all the genotypes that produce plants showing both dominant traits.
    b. How many of those showing both dominant traits are homozygous for both traits? Express your answer as a fraction out of sixteen.
    c. How many of the offspring out of sixteen are homozygous recessive for both traits?

You have now completed the study of simultaneous inheritance of two traits. You are ready to apply the knowledge of dihybrid crosses to a genetics problem. Try this one.

Science Skills

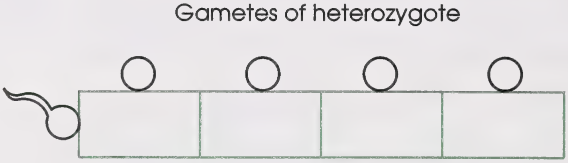
- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

13. Cross a plant that is heterozygous for both tall stem and purple flower colour with a plant that is homozygous recessive for both traits. Remember that tall stem *T* and purple flower colour *P* are dominant to short stem *t* and white flowers *p*.
    a. Genotype of parents:

Heterozygous plant = __________; gametes = ______________

Homozygous plant = __________; gametes = ______________

b. Draw a Punnet square showing the possible genotypes of F$_1$'s. Since all gametes from the homozygous plant are the same, only one line needs to be drawn on the Punnett square. Draw four lines if you find this is easier to understand.



c. Give the genotypic and phenotypic ratios of the F$_1$'s.

14. If you had a tall plant with purple flowers, how would you determine whether it was pure-breeding or a hybrid for both traits?

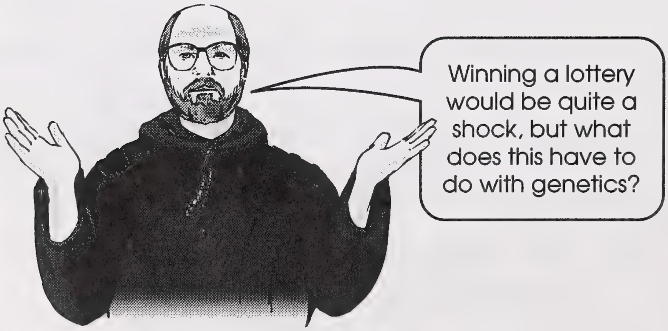
Check your answers by turning to the Appendix, Section 3: Activity 3.

When a hybrid individual produces two or more kinds of gametes each carrying contrasting genes, what are the chances that one kind will fertilize the gametes of the other parent. To answer this question you must look at probability which is covered in the next activity.

ACTIVITY

4 Probability – Luck of the Draw

What are the chances of a person winning the Lotto 649 lottery? One chance in ten million? What are the chances of a person being struck by lightning? One chance in two million? If you are more likely to be struck by lightning than winning the lottery, then which should you be more concerned about?


Winning a lottery would be quite a shock, but what does this have to do with genetics?

Nelson BIOLOGY

Your textbook covers the topic of probability on pages 482 and 483. Read through the first column of this material on page 482 before proceeding further.

Probability can be defined as a study of the chance that certain events or phenomena will happen.

1. a. How does your text define the term *probability*?

   b. In what form does the text express probability?

   c. Can you think of any other way it could be expressed?

Probability is important in genetics because it helps to explain the frequency of genotypes and phenotypes in offspring. It is also useful in genetic counselling, giving parents an idea of what chance they have of passing on a trait given that one or both are carriers of the gene(s) for the condition.

The following investigation gives you the opportunity to study probability and to transfer your understanding of chance to the genetics covered so far.

Investigation: Calculating Probability

Objective

The objective of this investigation is to study probability associated with tossing coins.

Materials

- paper*
- pencil*
- a small cup*
- two coins of the same denomination*

*supplied by student

Procedure

- Place one coin in the cup. Cover the cup opening with your hand and shake; then toss the coin on the table. Repeat ten times. Record the number of heads and tails you got in Table A.

- Using the same procedure, toss one coin fifty times. Record the number of heads and tails in Table B and place the totals at the bottom when you have completed your tosses.

- Toss two coins at the same time forty-eight times using the same procedure as before. For each group of eight tosses, record in Table C the number of double heads, one head one tail, and double tails that you get. Place the grand total of each combination tossed at the bottom of the table.

Science Skills

☐ A. Initiating
☑ B. Collecting
☑ C. Organizing
☑ D. Analysing
☐ E. Synthesizing
☑ F. Evaluating

- In this exercise you want to toss three consecutive heads tossing one coin or, to speed up the process, toss three coins together and attempt to get heads on all three coins on the same toss. Before you start, predict what your chances are of getting heads on all three coins. Now try it, keeping count of the number of attempts made till you get the first set of three heads. Record the number of tosses it took in the Table D. Try it again and record the number of tosses.

Observations

A.

Heads	Tails

B.

Heads	Tails

C.

	Trials (Sets of 8)						Total
2 Heads							
1 Head 1 Tail							
2 Tails							

D.

Trial #1	
Trial #2	

Analysis and Interpretation

2. a. When tossing one coin, what is the chance that you will get a head on any one toss?

   b. What is the chance you will get a tail?

3. Theoretically, when you toss a coin ten times, how many heads and how many tails should you get? Check your results to see how close you were to this expected ratio.

4. Was the ratio of heads to tails closer to 1:1 when you tossed the coin fifty times than it was when you only tossed it ten times?

5. What generalization can be made about the number of times an event must occur to get the actual results near to or as predicted?

6. Theoretically, if you toss two coins together forty-eight times, how many times should you get

   a. two heads b. a head and a tail c. two tails

7. Compare your actual results from Table C to the predicted results made in question 6. What could you do to get the actual results even closer to the theoretical numbers?

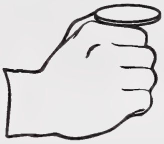
8. In the last part of the Procedure you are verifying the product rule.

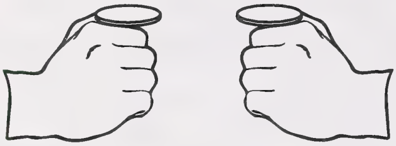
   a. What does this rule state?

   b. According to this rule how often should three consecutive heads come up on the average?

Check your answers by turning to the Appendix, Section 3: Activity 4.

The laws of chance can be summarized as follows:

If you toss a coin once,  the chances are exactly even that it will land *heads* one in two times. or *tails* one in two times.	Similarly, if you are heterozygous with one dominant factor and one recessive factor, *Aa* the odds are exactly even that offspring will receive *A* the dominant gene one in two times. or *a* the recessive gene one in two times.

If you and another person each tossed a coin,  the odds are	Similarly, if both you and your mate each carry heterozygous factors for some trait, You *Aa* Your mate *Aa*
one in four times for both heads; Head Head	with each child the chances are exactly one in four times the child will receive both dominant *AA*;
two in four times for one heads, one tails; or Head Tail	two in four times the child will receive one dominant, one recessive *Aa*; or
one in four times for both tails. Tail Tail	one in four times the child will receive both recessive *aa*.

Refer back to the results of Mendel's monohybrid cross on page 472 of your textbook.

9. Do his F_2 results conform with the probabilities and ratios previously summarized?

Now apply the concept of probability to a dihybrid cross. Your textbook discusses this on page 482 and 483 using widow's peak hairline and free earlobes as the inherited traits.

10. What is the general rule for determining the probability of inheriting two specific traits at the same time?

11. What are the chances that the two heterozygous individuals for widow's peak and free earlobes *EeWw* mentioned on pages 482 and 483 will have a girl with a straight hairline and attached earlobes?

12. In humans, Rh^+ blood is dominant to Rh^-. A man and woman are both Rh^+, but their first child is Rh^-.

    a. What is the chance that their next child will be Rh^-?

    b. Calculate the probability that the next child will be a Rh^+ girl.

13. In guinea pigs, black coat colour is dominant to white.

    a. What is the probability that a heterozygous black guinea pig crossed with a white one will produce a white offspring?

    b. What is the predicted ratio of black to white offspring from this cross?

14. In peas purple flowers are dominant to white. Give the most probable genotype of the parents in each of the following situations given the parental phenotypes and the ratio of contrasting features in the offspring.

Parental Phenotypes	Purple Progeny	White Progeny
a. purple and purple	118	38
b. purple and white	82	78
c. purple and purple	102	0

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Using the rule of independent events and the product rule, consider the probabilities for the following dihybrid cross.

15. Some dogs bark while others are silent when trailing prey. The barking characteristic is due to a dominant gene *B*. Erect ears *E* are dominant to drooping ears *e*.

    a. If you crossed a dog heterozygous for both traits with a droopy-eared, silent trailer, what are the chances that one of their offspring will be dominant for both traits (erect eared, barking trailer)?

    b. What are the chances of these two dogs producing a droopy-eared, silent trailer?

    c. If two dogs heterozygous for both traits were crossed, what would be the chance of them producing a droopy-eared, silent trailer?

Check your answers by turning to the Appendix, Section 3: Activity 4.

Your experience has probably taught you to appreciate the randomness of chance if you have ever had to guess a coin toss. In general, the more often an event occurs, the closer the actual frequency comes to the predicted. Sometimes you think you know the probability of an event occurring, but to your dismay it doesn't happen! You discover later that you were lacking some key information. Consider the case in the next activity.

ACTIVITY

5

A Case of Blending and Multiple Alleles

Larissa's tomcat Smokey was her pride and joy; dusty grey with chocolate brown spots, he was unique in the neighbourhood. One day a new family moved in next door. To Larissa's surprise they had a female cat also grey with chocolate spots. When they discovered Larissa's cat, they immediately requested its siring services. Ten weeks later the female gave birth to six kittens. Hopes of the unique grey and chocolate combination were dashed as only one kitten, a male, showed the parental colours. Four kittens were solid grey and a fifth was completely white.

Why are there three phenotypes instead of two as was the case in all monohybrid crosses studied so far? Here is a curious genetic phenomenon inconsistent with Mendel's observations. What is the explanation?

Read the section of your text entitled Incomplete Dominance on pages 476 and 477 to learn more about such traits.

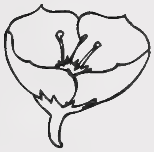
1. What trait in snapdragons indicates neither allele for colour is dominant?

2. Distinguish between codominance and incomplete dominance.

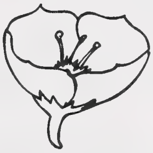
Four-o'clock flowers occur in two pure-breeding varieties, one with white flowers and the other with red flowers. If these are crossed all the F_1's have pink flowers.

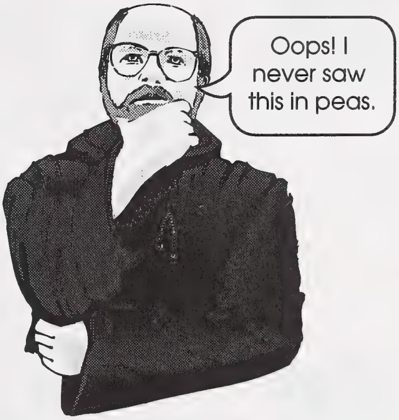
3. Give the genotype of each parent and the F_1's of such a cross. Use *r* and *w* to represent the alleles for red and white respectively.

Red four-o'clock



White four-o'clock




Oops! I never saw this in peas.

a. genotype = ________ b. genotype = ________

c. F_1 genotype = ________

The phenotype of the F_1's is pink flowers that appear to be a blend of the two originals. It is an intermediate type.

4. If Mendel had studied four-o'clocks, what principle would he not have proposed as a result?

5. Complete the chart for the cross of two F_1 four-o'clock plants.

Pink F_1 plant

a. genotype = ________

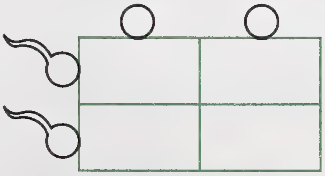
Pink F_1 plant

b. genotype = ________

c. gametes = and

d. gametes = ○ and ○

e. F_2 genotypes



f. How does the phenotypic ratio change for a monohybrid cross with no dominance as compared to a Mendelian cross where there is dominance?

6. In the case of codominance and incomplete dominance, pure-breeding individuals are easily identified. Explain this statement.

Study the chart on page 477 of your text showing inheritance of coat colour in shorthorn cattle and answer question number 7.

7. Use a Punnett square to find the chance of producing a red shorthorn if you cross a roan with a red shorthorn.

8. Can you generally explain the results of breeding Larissa's tomcat with the neighbour's spotted cat?

Mendel concluded from his work with peas that two kinds of factors controlled every trait and that each individual had a pair of these factors, one inherited from the mother and one from the father. In each case one factor was dominant to the other. As you have just learned with spotting in cats and four-o'clock flower colour, exceptions to dominance exist. You also may not find it surprising to discover that more than two alleles may affect the same trait.

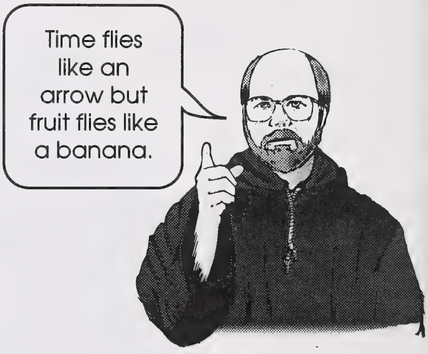
Multiple allelic traits are described in your textbook on pages 475 and 476. Read this carefully before you proceed any further.

9. How many alleles control eye colour in fruit flies? List them.

10. How many alleles does a fruit fly inherit for eye colour?

11. Give the possible genotypes for a fruit fly with red eyes from Table 20.1 on page 476.

12. What must be the genotype of two red-eyed fruit flies in order that some of their offspring will be white eyed?


Time flies like an arrow but fruit flies like a banana.

In humans, ABO blood type is a multiple allelic trait. The three different alleles I^A, I^B, and I^O produce four different blood types: A, B, AB, and O. You only inherit two alleles for blood type, one from each of your parents. See the genotypes possible for each blood type on page 479 of your text and the sequence of dominance for the three alleles.

13. If you know your blood type, what is your possible genotype?

14. If everyone in your immediate family has blood type A except one of your brothers or sisters who has blood type O, then what must be the genotypes of your parents?

15. Find out who the murderer was in the Case Study on page 479 of your text.

Check your answers by turning to the Appendix, Section 3: Activity 5.

Follow-up Activities

If you had difficulty understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

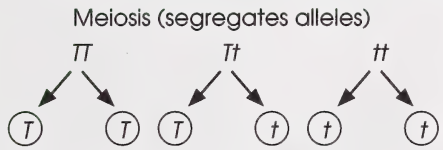
Extra Help

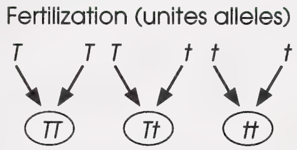
The two charts summarize Mendelian inheritance. Study them carefully to get an overall perspective of these inheritance patterns.

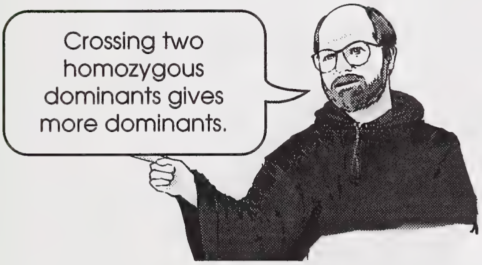
Monohybrid Cross

One trait example: height

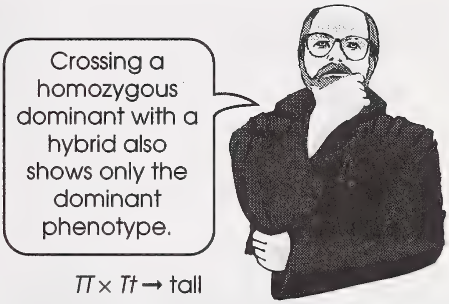
Two phenotypes	Three genotypes
Tall or short	*TT* homozygous dominant *Tt* heterozygous *tt* homozygous recessive



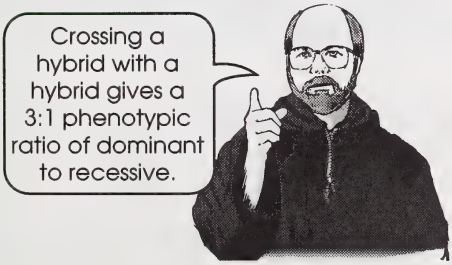



Crossing two homozygous dominants gives more dominants.

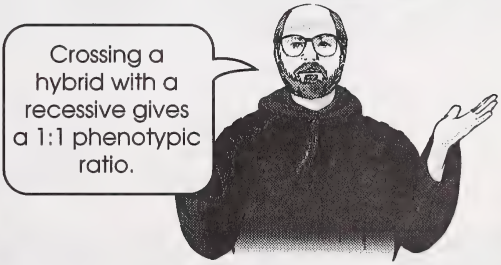
$TT \times TT \rightarrow$ tall


Crossing a homozygous dominant with a hybrid also shows only the dominant phenotype.

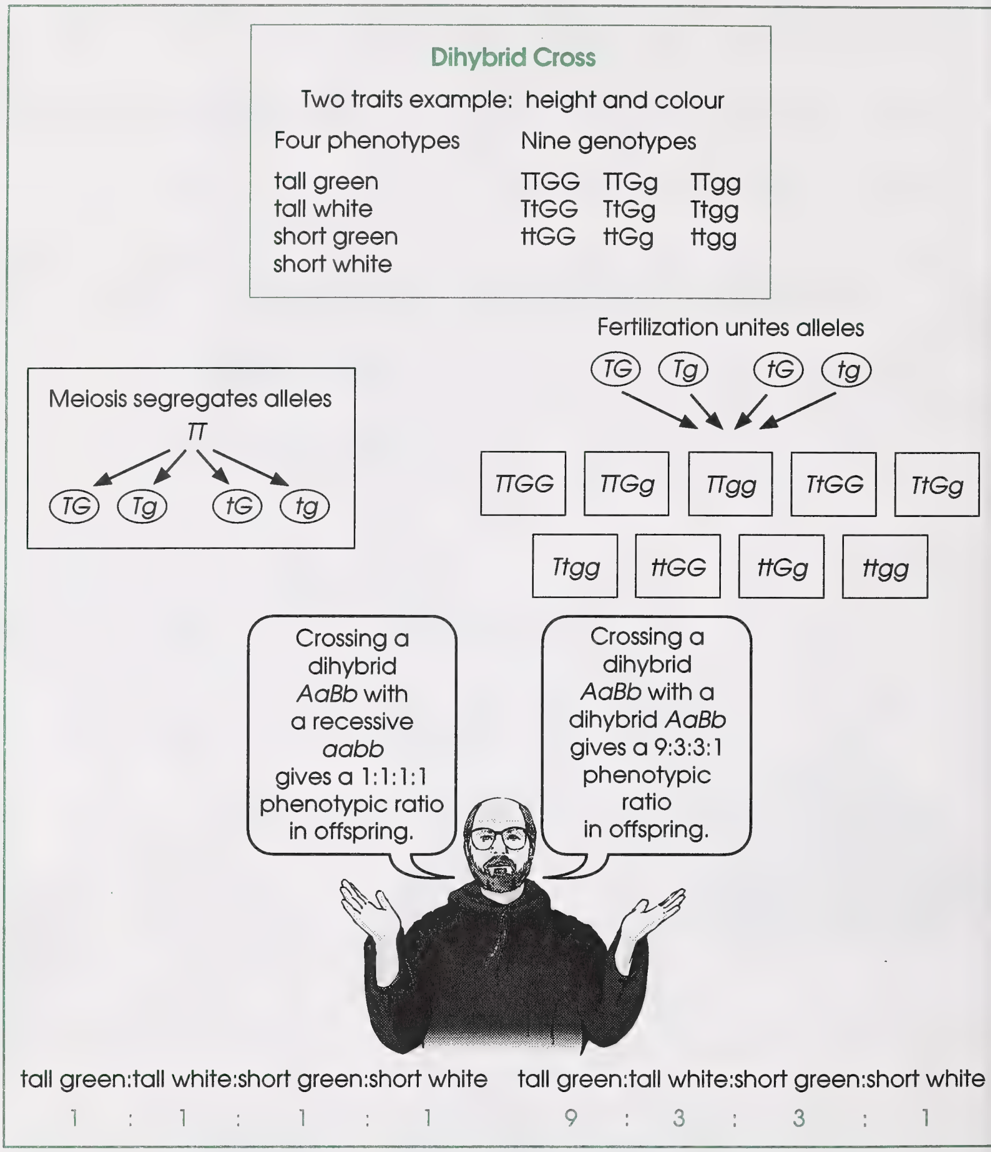
$TT \times Tt \rightarrow$ tall


Crossing a hybrid with a hybrid gives a 3:1 phenotypic ratio of dominant to recessive.

$Tt \times tt \rightarrow$ tall:short
3:1


Crossing a hybrid with a recessive gives a 1:1 phenotypic ratio.

$Tt \times tt \rightarrow$ tall:short
1:1


Dihybrid Cross
Two traits example: height and colour
Four phenotypes
tall green
tall white
short green
short white
Nine genotypes
TTGG TTGg TTgg
TtGG TtGg Ttgg
ttGG ttGg ttgg
Meiosis segregates alleles
TT
TG Tg tG tg
Fertilization unites alleles
TG Tg tG tg
TTGG TTGg TTgg TtGG TtGg
Ttgg ttGG ttGg ttgg
Crossing a dihybrid AaBb with a recessive aabb gives a 1:1:1:1 phenotypic ratio in offspring.
Crossing a dihybrid AaBb with a dihybrid AaBb gives a 9:3:3:1 phenotypic ratio in offspring.
tall green:tall white:short green:short white
1 : 1 : 1 : 1
tall green:tall white:short green:short white
9 : 3 : 3 : 1

Modern genetics shows that not all traits are controlled by just two contrasting alleles, nor is there always dominance as Mendel seems to have suggested. These variations to the Mendelian theme result in greater variability in phenotypes.

View the video Organic Evolution Series: *Factoring in Mendel* and answer the following questions for a good review of Mendel's discoveries.

1. Describe the weakness in Darwin's theory.

2. Briefly state Mendel's initial prediction of the results of crossing a pure round pea with a pure wrinkled pea.

3. What actually happened in the cross in question 2?

4. How did Mendel test his hypothesis that the wrinkled characteristic was somehow hidden in the new round peas?

5. Describe the results of Mendel's test cross.

6. Summarize Mendel's final conclusion.

7. Show how the *Rr* genotype could form from a cross of a pure round and a pure wrinkled parent.

8. What trait will the *Rr* hybrids show?

9. Complete this statement: Units of heredity are not blended. From one generation to the next they are ____________.

10. What term is used today for the factors of heredity?

11. What term designates each gene?

12. What term describes how a gene appears?

13. What term now describes the actual combination of alleles that make up the gene?

The Hardy-Weinberg principle will be discussed in later modules in this course, but watch the rest of the video to see where you are going.

14. Summarize the basic question that is asked at the end of the video and compose an answer based on what you've studied in this module.

Check your answers by turning to the Appendix, Section 3: Extra Help.

For a review of meiosis and a good comparison of mitosis to meiosis, watch the video Organic Evolution Series: *The Meiotic Mix* and answer the following questions.

15. Summarize the key points in Mendel's proposal.

16. Explain how Mendel's conclusion would support natural selection and evolution.

17. Mendel's theory of traits and subsequent knowledge of mitosis explained genetic continuity in species. Why did it not provide an explanation for variation?

18. Why can't gametes generally be formed by mitosis?

19. What is the solution to the problem in question 18?

20. Using the terms *diploid* and *haploid,* draw a simple concept map comparing the products of mitosis and meiosis.

21. What term describes how chromosomes are selected to go into gametes?

22. If alleles *Rr*, *Tt*, and *Dd* occur to form genes in a cell, illustrate all possible combinations that could form in gametes.

23. About how many combinations exist for twenty-three chromosomes?

24. What other genetic event increases variation besides random assortment?

25. What seems to be the result of this constant variation?

Check your answers by turning to the Appendix, Section 3: Extra Help.

The following questions are intended to help you develop a better understanding of the basic principles of genetics covered in this section.

26. Label each description given as a genotype or phenotype.

    a. yellow flowers   b. *Yy*   c. black, rough guinea pig   d. *BbRr*

27. Match the following terms to the appropriate phrases.

    - product rule
    - *AB*, *aB*
    - 3:1
    - 9:3:3:1
    - blending
    - chance
    - *TTPp*
    - factor
    - *AB*, *Aa*, *BB*
    - fertilization
    - *RrYy*
    - 1:1:1:1

    a. process by which gametes combine to restore the paired state of factors

    b. what Mendel called a heritable structure that controls a particular trait

    c. a phenotype that appears as an intermediate of the two contrasting forms

    d. a genotype that represents a dihybrid

    e. the predicted ratio of dominant to recessive individuals in a monohybrid cross

    f. possible gametes of an individual with a genotype of *AaBB*

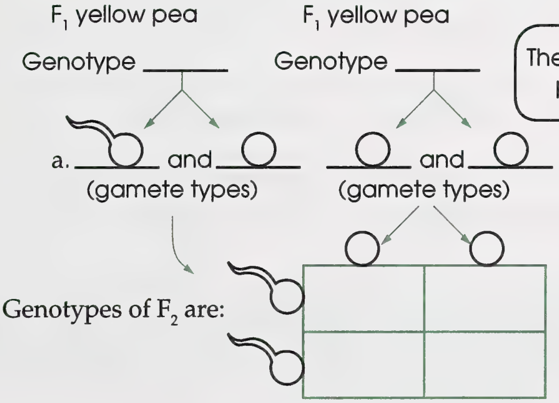
g. a pea plant homozygous for tallness *T* but heterozygous for flower colour *P*

h. predicted phenotypic ratio of a dihybrid cross *AaBb* and *AaBb*

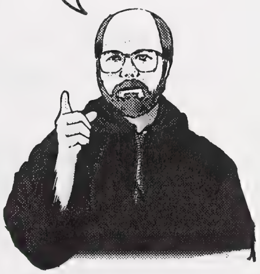
i. the element that can make the actual ratio of phenotypes different from the predicted

j. the chance that three tails will come up one after another when flipping coins

28. Using *Y* to represent the factor for yellow pea colour and *y* to represent the factor for green colour, show the resulting genotypes in the F_2 generation when Mendel crossed his F_1 yellow peas.



b. Genotypes of F_2 are:



The genotype of the F_1 yellow pea plants would be *Yy*.

c. What are the phenotypes of the offspring in this cross?

29. In sheep, consider black coat colour to be dominant to white for this question. Assume the factor representing black coat colour in sheep is *B* and the factor for white is *b*. Use this information to answer the next questions.

a. What is the genotype for a homozygous black sheep?

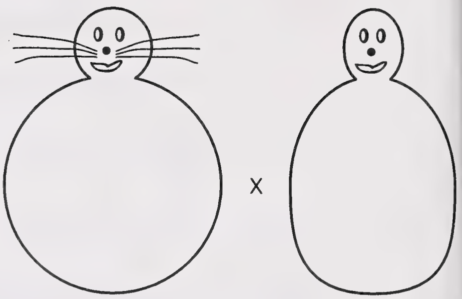
b. What must be the genotype of any white sheep?

c. The genotype of a sheep is *Bb*. What must be its phenotype?

d. If you bought a sheep that was black, how could you find out if it was purebred or not? Show the results of your test crosses.

e. If you did not want any white sheep, what genotype of parents would you choose to ensure none of the offspring would turn out white in colour?

30. In the world of Outland, oval shape *O* and whiskers *W* are dominant to round shape *o* and lack of whiskers *w* in local inhabitants called schmoos. A pure-breeding, whiskered round schmoo, genotype *WWoo*, is mated with a pure-breeding, non-whiskered oval one, genotype *wwOO*, and all the offspring are whiskered ovals.



a. Is this a monohybrid or dihybrid cross?

b. What kinds of gametes does each parent produce?

c. What is the genotype of the F_1's?

d. Using a Punnett square, show what the genotypes and phenotypes would be for the F_2 generation if two F_1's were mated.

31. A blue-coloured Andalusian rooster is mated with a blue hen. Some of the chicks are black, some are white, and about half of them are blue. Explain the results of this cross.

Check your answers by turning to the Appendix, Section 3: Extra Help.

Enrichment

There are a number of human traits that show a simple Mendelian pattern of inheritance with only two contrasting factors controlling them, one being dominant, the other recessive. Do the following investigation to find out more about them.

Science Skills

☐ A. Initiating
☑ B. Collecting
☑ C. Organizing
☑ D. Analysing
☐ E. Synthesizing
☑ F. Evaluating

Investigation: Exploring Human Hereditary Traits

Objective

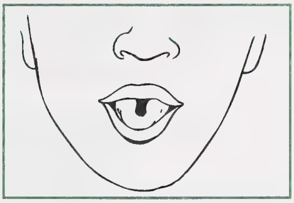
The objective of this investigation is to look at some traits in humans that follow the Mendelian rules of inheritance and to determine your genotype for each of them.

Materials

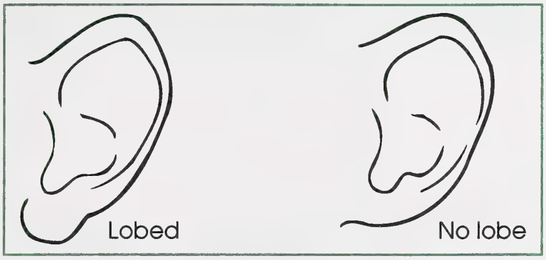
- pencil
- data table

Background Information

Read carefully through the following described list of traits to become familiar with them so as to be able to recognize them. Each of the traits listed are controlled by a dominant factor.



- Tongue rolling *R*: While facing a mirror or a partner, stick out your tongue and try to roll up the sides so that the tongue forms a U shape. The recessive contrasting form of this is not being able to form the U shape.



- Free earlobes *F*: The lobe at the bottom of the ear hangs freely below the point at which it is attached to the head. Having no lobe is recessive *f*.
- Straight thumb *N*: When raised from the hand the top segment of the thumb forms a straight line with the bottom segment; it does not bend backward as in a hitch-hiker's thumb which is recessive *n*.
- Widow's peak *W*: The mid-point of the hairline along the forehead dips downward. The recessive feature is a straight hairline across the forehead *w*.
- Left-over-right thumb cross *L*: When the hands are brought together to interlink the fingers in a natural hand fold, the left thumb crosses over the right. The recessive trait is crossing of the right thumb over the left *l*.
- Chin cleft *C*: The center of the chin has an indentation resembling a deep dimple. No indentation is recessive *c*.
- Straight little finger *S*: The last segment of the little finger forms a straight line with the bottom segment. The recessive variation is the upper half bending inward toward the hand *s*.
- Mid-digital hair *H*: Hair is present on the middle segment of the fingers. No hair is recessive *h*.

Procedure

If possible, work with a partner to help you determine whether you do or do not have each of these traits.

- Depending on whether or not you possess the trait, write *yes* or *no* for each trait in the student phenotype column of the data table.

- Find out whether each feature appears in your mother and your father. Record these observations in the data table.
- Determine your genotype or likely genotype for each trait once you have made all your observations.

Observations

Trait	Student Phenotype (yes/no)	Mother's Phenotype (yes/no)	Father's Phenotype (yes/no)	Student's Likely Genotype (Use letters given.)
Tongue rolling (*R*)				
Free earlobe (*F*)				
Straight thumb (*N*)				
Widow's peak (*W*)				
Left-over-right thumb crossing (*L*)				
Chin cleft (*C*)				
Straight little finger (*S*)				
Mid-digital hair (*H*)				

Analysis and Interpretation

1. a. If both you and your parents show the dominant trait chin cleft, could you be absolutely certain of the genotype of your parents or yourself for this trait? Explain.

   b. What phenotype would you look for in your brothers and sisters that would tell you that both your parents are heterozygous for this trait? Explain.

2. If both your parents were heterozygous for chin cleft and so were you, what would be your genotype (s)?

3. Discuss any adaptive value of the dominant traits you have studied in this investigation.

4. Compare your traits with other members of your community. Which variation of each trait is more common, the dominant or the recessive? How can this be explained?

Try the following genetics questions.

Nelson BIOLOGY

5. Most tigers in zoos are reddish-brown to rust-brown with dark stripes. Every so often a white tiger is born to normal coloured parents. It turns out that all white tigers in zoos are descendents of a white male that was captured in Rewa, India. When this tiger mated with normal pigmented females, all the offspring produced from that cross were reddish-yellow in colour. Only when he was mated with his daughters did the white coat reappear in the next generation. How could these results be explained?

6. Do Review question 12 on page 489 of your textbook.

Check your answers by turning to the Appendix, Section 3: Enrichment.

Conclusion

Imagine the number of genes that have been passed from the grandmother (on left) to her granddaughter (on right). Can you see the evidence of the genes?

Before Mendel's work in genetics during the mid-1800s, understanding of inheritance was confined to speculation and unsubstantiated generalizations. The prevailing opinion of the time was that blending of traits always occurred when individuals with contrasting features were crossed.

Mendel's work with pure-breeding strains of peas showed that this did not happen. He discovered that specific genetic instructions for identifiable traits were carried from parents to offspring via the gametes, and that these units of instruction remained distinct from generation to generation. These units he called factors. For the traits studied in peas, Mendel found that two different factors appeared to be involved, each producing a contrasting effect to the other. He also found that one of these factors was dominant, suppressing the expression of the other factor in the hybrid; thus, he proposed the principle of dominance. The inheritance of one trait was independent of the inheritance of another because the factors assorted independently of one another. This became Mendel's Law of Independent Assortment. He also determined that the frequency of specific phenotypes were predictable conforming with the laws of chance.

More recent work in genetics reveals that variations to Mendelian inheritance do exist. In some cases alleles do not show dominance, and in other cases more that two alleles affect one trait. Many traits are actually controlled by two or more gene pairs.

40

Section 3 Assignment: Classical Genetics

Review the Evaluation information found in the introductory pages of this module.

Response Page Setup

It is important to number and clearly identify each page with the following information at the top:

Biology 30 – Module 4 Section 3 Assignment Page # Name and ID#

Be sure to write legibly. Leave a wide left margin and number all of your pages.

Carefully read each of the following multiple choice questions and decide which of the choices **best** completes the statement or answers the question. Each question is worth 1 mark.

1. Identical twins have many similar characteristics mainly because they

   A. developed from two eggs which contained the same number of chromosomes
   B. were exposed to the same parental environment
   C. represent two individuals born at the same time of the same parents
   D. arose from the same fertilized egg

2. An individual with group AB blood marries an individual with group O blood. Their offspring can be

   A. either group AB or group O
   B. either group A or group B
   C. either group A or group O
   D. group A, B, AB, or O

3. A certain human female produced 444 mature eggs throughout her lifetime. How many eggs were probably alike in regard to genotype?

   A. none
   B. 111
   C. 222
   D. 444

4. Which of the following crosses would probably yield some completely homozygous recessive offspring?

   A. *Ttrr* × *TTrr*
   B. *TtRr* × *ttRR*
   C. *ttRR* × *TTrr*
   D. *TtRr* × *ttRr*

5. In the cross *Aa* × *Aa*, what portion of the offspring will have the same genotype as the parents?

   A. one half
   B. one fourth
   C. three quarters
   D. all

Use the following information to answer questions 6 and 7.

B black (dominant)
b white
C = straight (dominant)
c = curly

A pure black, straight-tailed female mouse mated with a pure white, curly-tailed male. The progeny from this litter mated.

6. What is the genotype of the F_1 generation?

   A. *BBcc*
   B. *bbcc*
   C. *Bbcc*
   D. *BbCc*

7. What is the number of different phenotypes that will be produced in the F_2 generation?

   A. 2
   B. 3
   C. 4
   D. 5

Use the following information to answer question 8.

In poultry, a crested head is produced by a dominant allele *C* and a plain head by its recessive allele *c*. Black feather colour *B* is dominant to red *b*. A heterozygous black-feathered, plain-headed bird is crossed with a homozygous red-feathered, crested-headed bird.

8. The genotype and phenotype of some of the F_1 individuals could be

   A. *bbCc*: red feathered, crest headed
   B. *Bbcc*: black feathered, plain headed
   C. *BBCc*: black feathered, crest headed
   D. *BbCc*: red feathered, crest headed

9. An abnormal number of chromosomes in human zygotes gives rise to conditions such as Down and Klinefelter syndrome. Such abnormal chromosome counts are commonly due to

   A. nondisjunction during meiosis
   B. mutation during meiosis
   C. crossing-over during formation of gametes
   D. no meiosis in the formation of gametes

10. In a family where the parents both expressed the dominant curly-haired trait and their first child has straight hair, what is the probability that their next child will be curly-haired?

    A. 0
    B. $\frac{1}{4}$
    C. $\frac{3}{4}$
    D. $\frac{4}{4}$

11. In pea plants, the gene for red flowers is dominant to the gene for white flowers. A heterozygous red-flowered plant was crossed with a white-flowered plant. What would the approximate ratio of the F_1 phenotype be?

    A. 3 red: 1 white
    B. 2 red: 1 white
    C. 1 red: 1 white
    D. 1 red: 3 white

12. If an organism of genotype *AA* mates with an organism of genotype *Aa* and 150 offspring are produced, the number of offspring with the genotype *Aa* will most probably be close to

    A. 120
    B. 30
    C. 70
    D. 0

13. According to the Law of Segregation, which types of gametes would be produced by a plant of the genotype *TtRr*?

    A. *Tt* and *Rr* only
    B. *TR*, *Tr*, *tR*, and *tr*
    C. *TR* and *tr* only
    D. *TR*, *Tr*, and *tr* only

14. The parents of offspring exhibiting a 3:1 phenotypic ratio are

    A. two homozygous individuals
    B. heterozygous for two traits
    C. heterozygous for one trait
    D. one homozygous and the other heterozygous

Science Skills

☐ A. Initiating
☐ B. Collecting
☐ C. Organizing
☑ D. Analysing
☑ E. Synthesizing
☐ F. Evaluating

15. If the factor *A* is essential for sight and the factor *B* results in blindness no matter what other genes are present, then the ratio of blind to normal offspring of the cross *aaBb* × *Aabb* will be

    A. 1:1
    B. 2:1
    C. 3:1
    D. 1:3

Reproduce the science skills assessment box after your response to this question. Remember to indicate your evaluation of your skill level for each identified science skill. Be sure to include the spaces for teacher assessment.

Self:	A. ☐	B. ☐	C. ☐	D. ☐	E. ☐	F. ☐
Teacher:	A. ☐	B. ☐	C. ☐	D. ☐	E. ☐	F. ☐

16. Match the correct term with the most appropriate phrase. **(5 marks)**

    a. two or more alternate forms of a gene

    b. term that refers to the combination of genes an organism has for a trait

    c. alleles are same for a particular trait

    d. the expression of the genes for a particular trait

    e. expression of two phenotypes occurs at the same time

    heterozygous
    monohybrid
    alleles
    phenotype
    homozygous
    codominance
    genotype
    segregation
    independent assortment
    dominant

17. A pure breed of chicken has been developed with silky feathers. When hens of this breed are crossed with roosters with normal feathers, all the F_1's produce normal feathers.

    a. Which form of feather is controlled by a dominant factor? **(1 mark)**

    b. If the F_1's were allowed to mate with each other, what genotypes and phenotypes would you expect in the F_2 generation? (N = normal; n = silky) **(2 marks)**

    c. What phenotypic ratio would be expected from the F_1 mating? **(1 mark)**

    d. If a total of 200 birds were produced in the F_2 generation, calculate the theoretical number that would be **(3 marks)**

       i. homozygous normal genotype
       ii. silky feathered phenotype
       iii. normal feathered phenotype

18. Straight wings in fruit flies are dominant over curly wings. Explain how you would determine whether a straight-winged fly is heterozygous or homozygous? **(1 mark)**

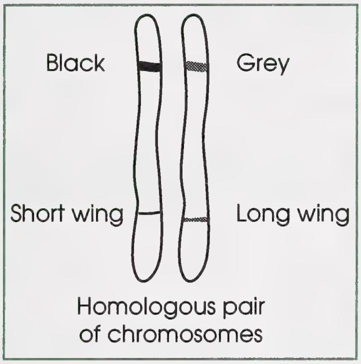
19. In certain cattle the polled (hornless) trait H is dominant over horns h. A polled bull is mated to a cow with horns. The first calf grows up and develops horns. The bull is then mated to another cow which is polled. Their calf also develops horns. Identify the genotypes of all individuals. **(3 marks)**

20. There are two varieties of width of leaf in Plant X. One produces a broad leaf and the other a narrow leaf. When these varieties are crossed, the offspring all have intermediate width leaves. **(2 marks)**

    a. How would you explain their result?

b. How many phenotypes would occur in the cross between two F_1 plants?

21. In his studies of inheritance in fruit flies, Morgan observed that the colour of the body could be grey or black and the wings could be long or short. Since grey body and long wing always appeared together as did black body and short wing, Morgan concluded that the genes were on the same chromosome (linked) as shown.



In his studies he discovered an occasional fly with grey body and short wings or black body with long wings. With the use of a diagram, explain what must occasionally happen to produce these unexpected types. **(2 marks)**

22. In guinea pigs, black coat *B* is dominant to white *b* coat, and short hair *S* is dominant to long hair *s*. A black long-haired pig is mated with a white short-haired one. Several litters were produced and out of the total of thirty-eight offspring, ten were black and short, nine were black and long, six were white and short, and thirteen were white and long. **(5 marks)**

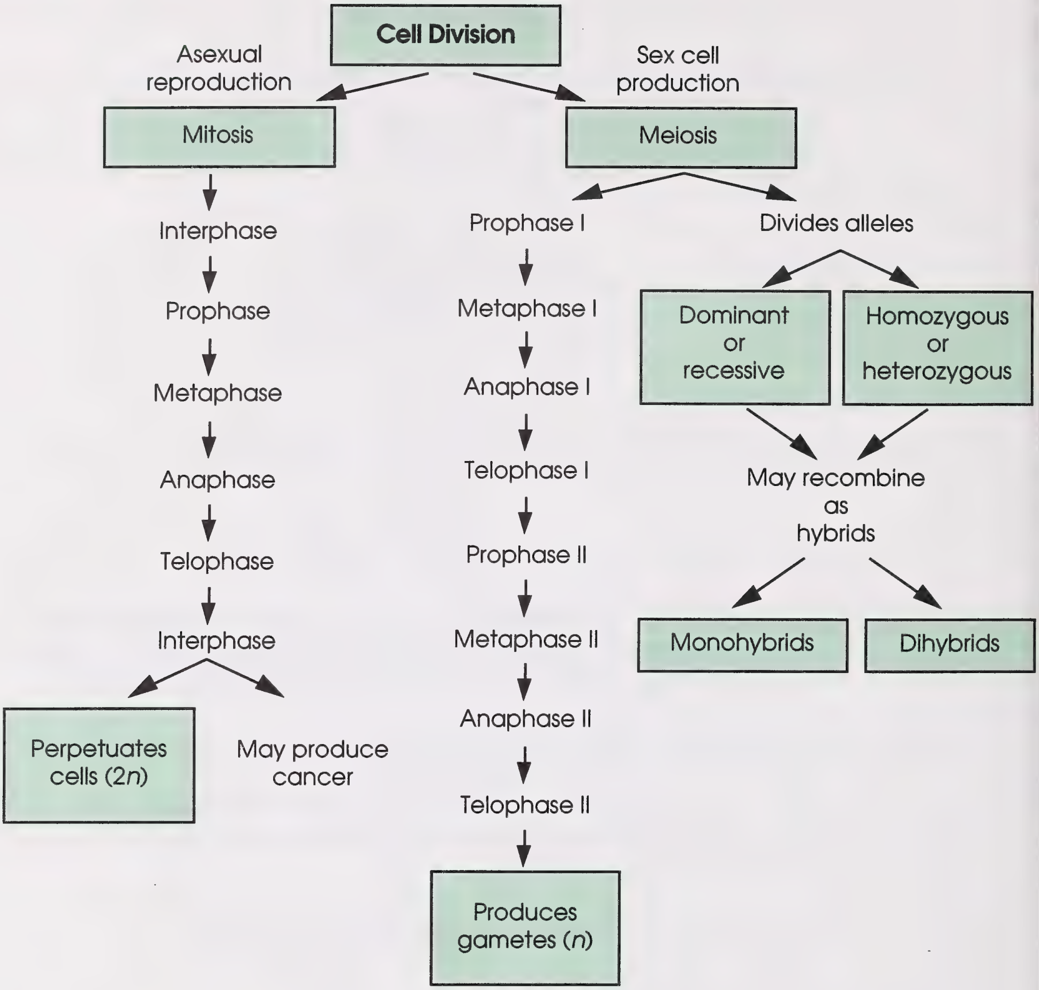
a. What are the most likely genotypes of the parents?

b. Show the possible genotypes of the offspring.

c. What should the phenotypic ratio be theoretically?

MODULE SUMMARY

You began this module with a study of how cells replace themselves with nearly perfect copies. Then you studied how organisms replace themselves with offspring. The offspring are not exact copies of their parents as cells are, but rather reflect a combination of characteristics of two parents. The module concluded with some of the mechanisms for the transfer of characteristics to future generations.

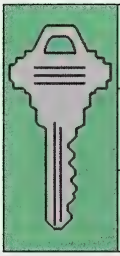


To ensure that all of your work has been completed in a satisfactory manner, check off the items in the following list:

- ☐ Section 1 Assignment has been completed.
- ☐ Section 2 Assignment has been completed.
- ☐ Section 3 Assignment has been completed.
- ☐ Your responses are organized and neat, with room for teacher comments.
- ☐ All your response pages are numbered consecutively and identified with this heading.

Biology 30 – Module 4 Section # Assignment Page # Name and ID #

Appendix



- Glossary
- Suggested Answers
- Human Karyotype Plates

Glossary

alternation of generation: a life cycle involving a sexual phase and an asexual phase

conjugation: a form of sexual reproduction in which genetic material is exchanged between two organisms but there is no increase in the number of organisms

F_1: first filial generation that inherits factors from the original parents ($P_1 \times P_1 \rightarrow F_1$)

F_2: second filial generation that inherits factors from the F_1 generation ($F_1 \times F_1 \rightarrow F_2$)

factor: a gene that produces a specific physical feature

gametophyte: the haploid stage of a plant that produces gametes which join and produce the sporophyte generation

hermaphroditic: condition of having both male and female sex organs in the same organism

hypotonic: lower concentration of solute; opposite to hypertonic

plasmolysed: as in plasmolysis, a process in which a cell absorbs water, swells, and bursts*

pollination: transfer of pollen from the anther to the stigma of a flower

segregation: the separation of the two factors for a trait during gamete formation so that each gamete receives only one factor

sporophyte: the diploid stage of a plant that undergoes meiosis and produces spores for reproduction of the gametophyte generation

translocates: a segment of a chromosome moves from one chromosome to another

***Note:** The term *plasmolysis* may sometimes be applied to cells that swell and burst in a hypotonic solution or shrink and collapse in a hypertonic solution; more specific terms may be used such as *cytolysis*, *hemolysis*, and *crenation*.

Suggested Answers

Section 1: Activity 1

1. The number of cells making up the average adult is approximately 100 trillion cells. The origin of all these cells is one fertilized egg (zygote).

2. a. Cell division is essential for repair (healing), the replacement of worn-out cells, as well as for growth of multicellular organisms.

   b. Replacement of damaged tissue was most important to the injured person.

3. Nerve cells are so specialized that they have little or no ability to undergo cell division. This explains why nerve tissue does not heal well when damaged and why his arm was still numb four years later.

4. Some questions that cannot be answered include the following:

   - Why does an egg cell divide so rapidly after fertilization?
   - How do cells know when to divide?
   - Why do some cells divide at enormous rates while others do not?
   - Why do cancer cells divide at uncontrolled rates?
   - How does the rate of cell division change in a cell's lifetime?

5. The second part of the cell theory states that all cells come from pre-existing cells by cell division.

6. Binary fission is a form of asexual reproduction among primitive single-celled organisms such as bacteria that leads to an increase in number of the organisms. It involves a splitting of cell material into two cells. Mitosis is the division of the nuclear material in a cell, followed by a division of cellular material to form two daughter cells. Nuclear material must be replicated before it can divide.

7. a. mother cell
   b. chromosome
   c. division of cytoplasm
   d. daughter cell
   e. mitosis
   f. chromatin

8. a. There would be forty-eight chromosomes in nerve and bone cells.

   b. There would be forty-eight chromosomes in each daughter cell.

9. Chromosomes are the coiled strands of genetic material that are visible during mitosis. Chromatids are copies of a chromosome existing as single strands of a double chromosome still attached to each other at the centromere. Chromatin refers to all the invisible uncoiled strands of chromosomes in a nucleus.

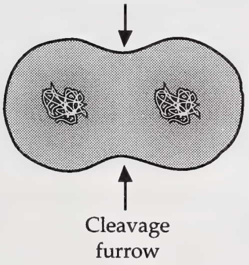
10. Centrioles provide attachment for spindle fibres and form the points to which chromatids are pulled during anaphase.

11. The five phases are interphase, prophase, metaphase, anaphase, and telophase. Interphase is generally not considered to be a phase of mitosis.

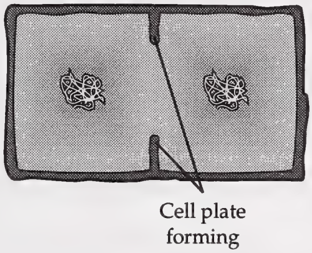
12. a. A b. A c. B d. B e. B f. C g. D h. E

13. Division of the cytoplasm is called cytokinesis. In animal cells the cytoplasm pinches off separating the two daughter cells, but in plant cells a new cell wall must form between the two nuclei because the existing cell walls are rigid and do not allow pinching. The new cell wall is called a cell plate.

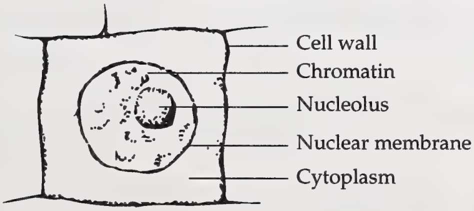
Animal Cell



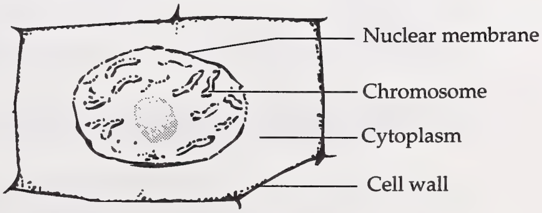
Plant Cell



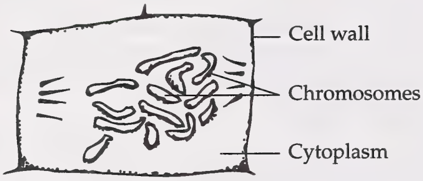
14. a. Interphase



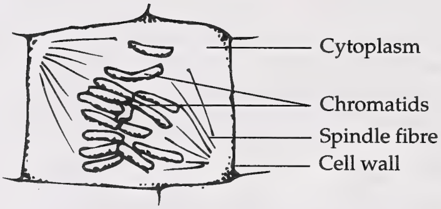
b. Early prophase



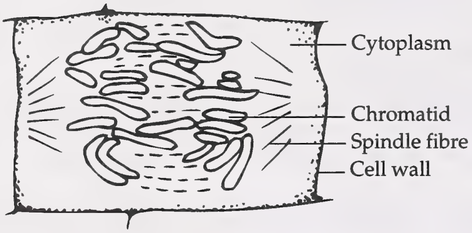
c. Late prophase



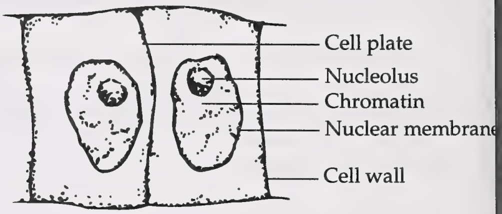
d. Metaphase



e. Anaphase



f. Telophase



15. a. and b.

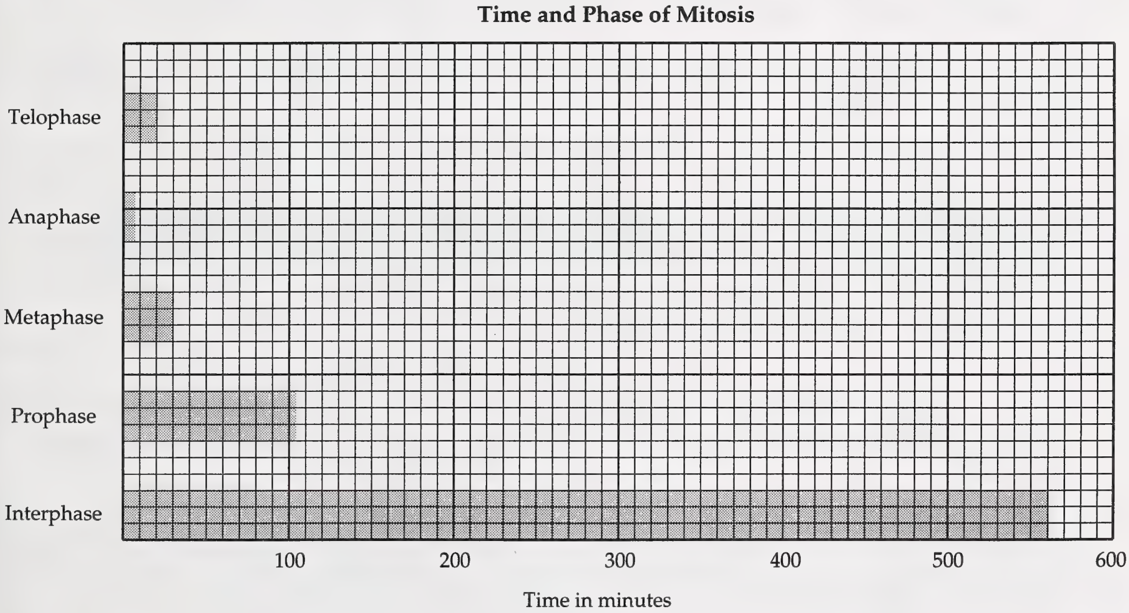
Phase	Area 1	Area 2	Area 3	Total Number of Cells in Each Phase	Time in Minutes
Interphase	95	75	84	254	561
Prophase	13	12	21	46	101
Metaphase	5	4	5	14	31
Anaphase	1	0	2	3	7
Telophase	3	2	4	9	20
			Total Number	326	720

16.
- **Procedure question a:** Cells of the meristematic region are shorter and more compact.
- **Procedure question c:** Plant cells are more angular (rectangular) and generally larger. The chromosomes in plants cells appear to be larger as well.
- **Procedure question d:** The number can vary greatly from one area of a slide to another. You may find fourteen cells in interphase and six actively dividing.
- **Procedure question e:** Your answer will depend upon the numbers obtained in question d. Using the figures from question d., the percentage would be 30%.
- **Procedure question f:** Again the numbers can vary greatly. For example, the numbers could be twelve cells in interphase and eight actively dividing.
- **Procedure question g:** Answer will be quite variable. The percentage of cells undergoing mitosis would be 40% if you use the numbers given in question f.

- **Procedure question h:** Using data from questions d and f, the percentage of plant cells undergoing mitosis is greater by 10%.

17. - **Application question 1:** The cell without some of the genetic material will be seriously affected and will likely die. The effects of having more than the normal number of chromosomes will vary.
    - **Application question 2:** Each daughter cell will have ten chromosomes.
    - **Application question 3:** An identical twin will be produced.
    - **Application question 4:** The cells divide at such a rapid rate that they do not specialize into different tissues. Without specialized tissues, plant cells are not provided with adequate levels of nutrients to support their growth so they die.

18. a. **Note:** This graph could also have been drawn vertically.



b. Interphase takes the longest time to complete.

c. The shortest phase is anaphase.

19. See the sketches given in the answer for question 14 in this Appendix.

20. See the table given in the answer for question 15 in this Appendix.

21. Mitosis must be organized and precise to ensure that each daughter cell gets a complete complement of chromosomes.

22. The crucial event is the duplication of the chromosomes.

23. The chromatid pairs coil up into short fat bodies that become visible through a light microscope. See Figure 18.4 on page 432 in your text.

24. The number of chromosomes in the original mother cell would have been twenty.

25. The cells go into interphase.

26. **Procedure question d**: See the answer given to question 16, Procedure question d. in this Appendix.

Section 1: Activity 2

1. Cloning is the process of producing identical offspring from a single cell of body tissue. Hydra clone by the process of budding off new individuals and strawberries clone by generating new plants on runners.

2. a. Fredrick Stewart grew a carrot plant from a single somatic (body) cell that had been removed from the tissues of another carrot plant.

   b. This technique has led to production of many useful agricultural and garden plants that are identical to their parents and that have predictable characteristics.

3. General details of cloning:

Plants Cloned Commercially	Plants That Cannot Be Cloned	Advantages of Cloning	Kind of Cells Needed for Cloning
orchids, carrots, ferns, tobacco, petunias, lettuce	grass, legumes such as clover, peas, alfalfa	production of plants with predictable and preferred traits	unspecialized or undifferentiated cells

4. The cells produced by mitosis up to the eight-cell stage can be used for cloning of mice. Cells taken after the eight-cell stage of development have already become too specialized and do not develop into complete individuals.

5. Totipotent refers to a cell's ability to grow from an egg to an adult.

6. Cloning may be used to generate new tissue, for example to replace burned skin or to produce parts of organs like the islet cells in the pancreas.

7. The problem of rejection of donor organs and tissues would be eliminated. Foreign tissue has different kinds of substances (proteins and carbohydrates) that the body would recognize as foreign. The body responds to these substances by producing antibodies against them leading to a gradual breakdown of the donor tissue (rejection). Since cloned tissue actually belongs to the person it will not be rejected.

8. Liver tissue is regenerative, meaning that its cells will actively undergo mitotic divisions and grow into a normal sized organ. The cells of the heart and kidney are too specialized and have lost the ability to actively divide.

9. a. Process X produces identical twins.

   b. Process Y produces fraternal twins.

10. Identical twins are clones because they arise from one fertilized egg. After the first or second mitotic division of the fertilized egg, cells separate with each growing into a distinct individual. Because the cells are all genetically identical, so are the twins.

    Fraternal twins come from two different eggs fertilized by two different sperm cells; thus, they have a different genetic complement which does not make them clones.

11. Research on cells grown in tissue cultures indicates that a biological clock regulates the number of mitotic divisions possible by a cell; i.e., cells appear to be capable of a fixed number of cell divisions. For example, if immature heart cells are frozen after twenty divisions, then thawed, they will undergo only thirty more divisions. If they are frozen after ten divisions and thawed, the number of subsequent divisions is forty. It appears that the total number of divisions possible for heart cells is fifty.

12. The two kinds of cells that escape aging are the sperm cells and cancerous cells.

13. Cancerous cells reproduce at such an accelerated rate that they do not have time to specialize. As non-functional cells they may crowd normal cells and disrupt tissue.

14.
    - Aging is caused by mutations of the genetic code or messages in the genes. No evidence for this hypothesis has been found.
    - Aging genes exist which shut down the chemical reactions within the body. No evidence is available for this hypothesis.
    - Aging occurs as cell lineages die out. As cells reach the end of their potential to divide, they die and are not replaced. Little evidence is available for this hypothesis.

Section 1: Activity 3

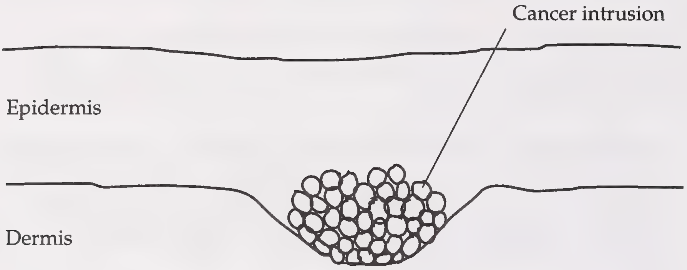
1. Cancer is a broad group of diseases characterized by a rapid, uncontrolled division of cells.

2. Properties of normal and cancerous cells in humans:

Type of Cell	Rate of Reproduction	Ability to Reproduce in Isolation (yes/no)	Ability to Differentiate (yes/no)	Number of Chromosomes	Adhere to Other Cells (yes/no)
Normal Cell	controlled by cell and cells adjacent	no	yes	46	yes
Cancerous Cell	rapid, uncontrolled	yes	no	varies	no

3. Metastasis is the movement of cancerous cells from one part of the body to another via the blood or lymph system. This spreading of the cancerous cells to a number of places in the body causes malignant tumours to grow in these new sites accelerating the disease and making it nearly impossible to cure.

4. **Procedure question a:** A sample of a line drawing is given.



5. - **Procedure question b:** Yes, the cells of the epidermis are invading the dermis.
   - **Procedure question c:** The size can vary but cancerous cells tend to be smaller. An example size would be 1.5 micrometres.
   - **Procedure question d:** The nucleus of a cancerous cell is larger than that of normal cells. An example size would be 0.8 micrometres.
   - **Procedure question e:** The answer can vary. If the nucleus is 0.8 µm and the cell diameter is 1.5 µm, then the ratio is 0.53/1.
   - **Procedure question f:** The normal cell has more cytoplasm and generally a smaller nucleus, so the nucleus-to-cytoplasm ratio will be larger than for a cancer cell.
   - **Procedure question g:** Sample answers:

Cell Type	Cell Size	Nuclear Shape	Nuclear Size
Normal Cell	2.0 µm	round	0.5 µm
Cancerous Cell	1.5 µm	irregular	0.8 µm

   - **Application question 1:** Cancer cells are much more active than the normal cells which would explain the larger nucleus. Another reason could be that cancerous cells may have more than the usual complement of chromosomes; thus, more room is needed to accommodate them. You'll study this further.
   - **Application question 2:** The malignant tumour can metastasize. This means that some of the cells from the tumour may dislodge and re-establish themselves in a new area resulting in a spreading of the cancer throughout the body.
   - **Application question 3:** The outer tissues of the body come in contact with many environmental agents that cause cancer thus skin cancer tends to be one of the most common forms of cancer.
   - **Application question 4. (a):** The organism may have cancer. Cancer cells divide so rapidly that they do not have time to differentiate. The nuclei may absorb more stain because they are more active.
   - **Application question 4. (b):** The rate of cell division could be monitored. The nuclei could be measured and the cell could be studied in tissue culture.

6. a. The total time needed for a normal chicken stomach cell to complete mitosis is 625 min.

   b. A cancerous chicken stomach cell takes a total of 448 min to complete mitosis.

c. Except for metaphase and anaphase, time spent in each phase is shorter in cancerous cells. The total time taken by cancerous cells is shorter. They divide more rapidly and spend less time in interphase.

7. The normal karyotype shows forty-six chromosomes. The cancer cell karyotype has fifty-one chromosomes.

8. Trisomy (three of one kind of chromosome) occurs in chromosome 8, 10, 12, 21, and 22. This creates the extra chromosomes.

9. The cancerous chromosomes in trisomy 22 differ in size. One is closer to normal. Two others are shorter.

10. The chromosomes are not identical. One is slightly larger.

11. Chemotherapy is a method of cancer treatment that involves the use of chemicals. The chemicals either inhibit cell division or kill actively dividing cells.

12. Patients lose their hair because the actively dividing follicular cells that grow the hair are also inhibited by the drug(s). When their cellular division is arrested, the follicular cells cannot support the hair follicles so the hair falls out.

13. Methotrexate inhibits the enzyme that is needed to replicate chromosomal material (DNA) prior to cell division.

14. It loses its effect over time because it also stimulates the cancerous cells to mass produce the genes that control the production of the DNA replicating enzyme. This leads to a marked increase in production of the enzyme restoring the cancerous cell's ability to reproduce.

15. Many plants, especially those in the tropics, are being destroyed before they are analysed for potential sources of medical drugs, including drugs to treat cancer.

Section 1: Follow-up Activities

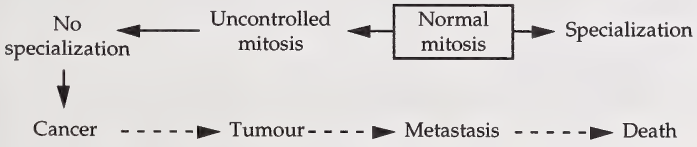
Extra Help

1. a. cytokinesis
   b. regeneration
   c. mitosis
   d. mother cell
   e. totipotent
   f. binary fission
   g. chromosome
   h. cloning
   i. centromere
   j. differentiation
   k. identical twins
   l. spindle fibres

2. a. interphase
   b. prophase
   c. metaphase
   d. early anaphase
   e. late anaphase
   f. early telophase
   g. late telophase
   h. daughter cells in interphase

3. a. telophase
   b. anaphase
   c. telophase
   d. interphase
   e. metaphase
   f. prophase
   g. metaphase
   h. telophase

4. The concept maps possible are quite variable. Here is one you might draw.



Enrichment

1. a. Telophase has the most significant time difference for the two organisms.

   b. The pea shows a time similar to that of the onion skin cell to complete mitosis. The similarity may be because they are both plants.

   c. The root could undergo more rapid growth because mitosis, which is responsible for growth, occurs at a more rapid rate in the root. This assumption could only be true if the time for interphase is about the same for the two organisms.

   d. No, you cannot conclude that plant cells take less time than animals cells to complete mitosis. A comparation of many species of plants and animals would have to be made before a generalization such as this could be made.

2. a. prophase = 12.8 min metaphase = 4.0 min anaphase = 0.8 min telophase = 2.4 min

   b. The bacterium doubles every 20 min and there will be seventy-two doublings in a 24-hour period. After only twenty-five doublings the bacteria would number 33 554 432. Seventy-two doublings would create an astronomical number, about 4.6×10^{20}.

3. Oncogenes are a recently discovered group of about twenty genes that exist in plant and animal cells, including humans, that are linked to the transformation of normal cells to cancerous cells. They exist in the cell in a dormant state controlled by a regulator gene. The regulator gene acts as a switch by turning cell division "on" or "off." In the case of cancer only the "on" portion is working.

4. Since growth is directly linked to mitosis you can assume the graph also represents a rate of cell division. The graph shows that the rate of mitosis is quite rapid during the first fifteen months of an infant's life but the rate is not constant. There is a gradual decline in the rate over this same time period. At the age of eighteen months the rate of cell division becomes equal to the rate of cell loss through cell death. At Point A cell division is much greater than cell loss. At Point B the difference between gain and loss is not as great. At Point C gain and loss are nearly the same.

5. The Canadian Cancer Society has numerous pamphlets and brochures. One brochure called *RESEARCH* describes annual research programs across Canada. Request a copy of this brochure and notice how many programs are related to genetics.

Section 2: Activity 1

1. a. Human cells formed by mitosis have forty-six chromosomes.

   b. Cells formed by meiosis have only twenty-three chromosomes.

   c. A fertilized human egg will have forty-six chromosomes.

2. a. A diploid cell has its full complement of chromosomes consisting of two sets. Chromosomes in this kind of cell are in pairs. A haploid cell has only one set of chromosomes. There is only one chromosome of each kind instead of two.

   b. All body cells are diploid. The only cells that are haploid are the sex cells, also called the gametes or the egg and sperm.

3. a. i. A ii. B and C iii. C

   b. There are two divisions; the first is meiosis I and the second is meiosis II.

4. Chromosomes containing genes for the same traits are called homologous chromosomes or homologues. They are similar in shape, size, and sequence of genes. Check the homologous chromosomes in Figure 19.9 on page 455 of your text.

5. One advantage could be that if some of the genetic material is defective in one set, it may be good in the second set, thus ensuring normality.

6. a. Process X would be meiosis because it produces haploid cells.

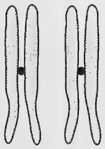
   b. Meiosis ensures that the chromosome number of a species does not keep doubling from one generation to the next. Meiosis also shuffles chromosomes producing new combinations in the gametes which leads to variability in the members of a species.

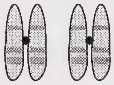
   c. Process Y is fertilization. It restores the diploid number of chromosomes in the zygote which gives rise to the offspring.

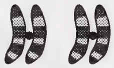
   d. Process Z is mitosis. It must occur to make the fertilized egg grow into a mass of cells that will become a new individual.

7. The four phases are prophase I, metaphase I, anaphase I, and telophase I.

8. There are three pairs of homologous chromosomes. The order in which you draw and number them is not significant.


Homologous pair 1

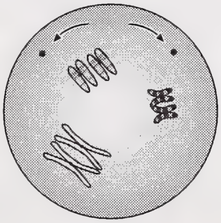

Homologous pair 2


Homologous pair 3

9. The major events of prophase are

   - The nuclear membrane dissolves and chromosomes spill out into the cytoplasm.
   - Centrioles separate and migrate to opposite ends of the cell.
   - Spindle fibres grow.
   - Homologous chromosomes come together forming groups of four chromatids called tetrads. Examine Figure 19.5 on page 450 in your text.

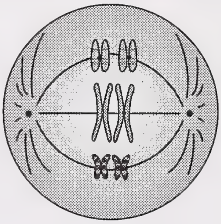
10. The completed sketch would look like this.



11. a. Synapsis is the pairing of homologous chromosomes (with their duplicates) to form a tetrad of chromatids. Crossing-over is the exchange of genetic material between the homologous chromosomes.

    b. Crossing-over contributes to new combinations of genes in gametes and thus greater diversity in individuals of a species.

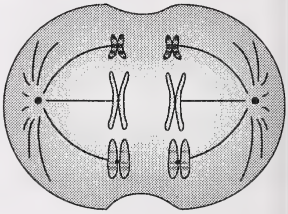
12. a. A sketch of metaphase I would look like this.



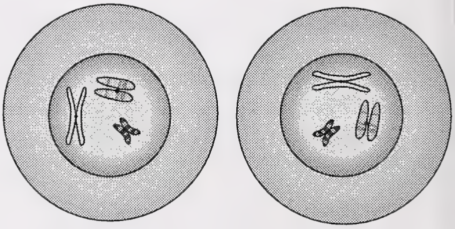
    b. Seven chromosome tetrads can be clearly seen in each of the cells.

13. a. Segregation is the separation of the homologous chromosomes as they are pulled to opposite poles by the spindle fibres.

    b. Segregation in Cell X is illustrated in the diagram on the right.

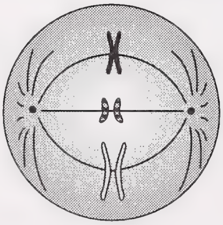


14. A sketch of the chromatid pairs in the daughter cells is shown on the right.

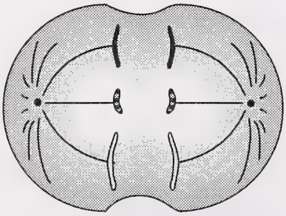


15. The chromatids are separated in meiosis II.

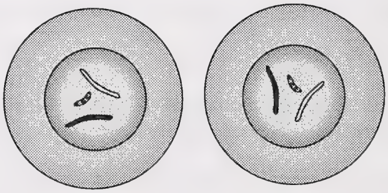
16. a.



Metaphase II



Anaphase II

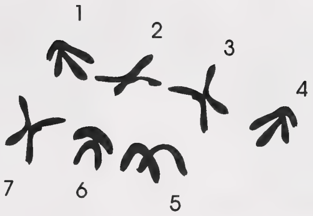


Telophase II

    b. i. prophase II
       ii. metaphase II
       iii. late metaphase II
       iv. anaphase II
       v. telophase
       vi. interphase

    c. Seven chromosomes can be seen in the cells in the third photo.

d. Your numbers can be arbitrary.



17. a. Four cells are produced each time a cell undergoes meiosis.

b. The four cells produced have only one set of chromosomes, half the number of the mother cells.

c. The cells produced by meiosis are used for sexual reproduction.

d. These cells are called sex cells, gametes, or just egg and sperm depending on which sex produced them.

18. a. reduction division
b. replication
c. homologous chromosomes
d. chromatids
e. gametes (haploid cells)
f. 3

19.

Gametogenesis in Humans

	Males	Females
Structure in which it occurs	testis	ovary
Name of process	spermatogenesis	oogenesis
Name of cell that begins meiosis	primary spermatocyte	primary oocyte
Cytokinesis (equal/unequal)	equal	unequal
Number of functional gametes produced per division	four	one
Name of cells produced	sperm	ovum, egg, or ootid
Relative size of cells produced	small	large

20. a. The cytoplasm is needed by the egg cell for nutrients and the organelles required for future cell divisions in the event that the egg becomes fertilized. The sperm cells, on the other hand, are mobile and must minimize the weight they carry.

b. The polar bodies disintegrate. They serve no useful purpose except to be the receptacles for the extra chromosomes not required in the making of the functional egg cell.

c. If a polar body did not separate, an egg would have too many chromosomes after fertilization.

21. Males can produce up to a billion sperm cells per day. This is possible because diploid spermatocytes that give rise to sperm cells are continually replenished by mitosis. Females, however, are born with about 400 000 oocytes of which only about 400 become functional eggs.

22. The spermatocytes are actively replenished and continue to undergo meiotic divisions producing sperm throughout a man's life. A woman's body produces a limited number of egg cells because she begins with a limited number of oocytes which are not replenished by mitosis. Once all the oocytes have gone through meiosis, the woman becomes infertile. This point in her life is called menopause.

23. Morgan called them sex chromosomes.

24. a. A female has two X chromosomes (XX).

    b. A male has one X and one Y chromosome (XY).

25. Autosomes are all the chromosomes excluding the sex chromosomes (X and Y). Normally there are twenty-three pairs in females, including X and X. In males there are twenty-two pairs plus X and Y.

26. a. Ova will all carry the X chromosome. Sperm will either carry an X or a Y chromosome.

    b. A male child gets the X chromosome from his mother.

Section 2: Activity 2

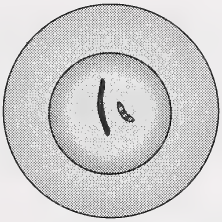
1.
   - **Procedure question a**: The strands of yarn represent chromatids and the paper clips represent the centromeres. The centre line represents the equatorial plate.
   - **Procedure question b**: The diploid number is four.
   - **Procedure question c**: The strands represent chromatids.
   - **Procedure question d**: There are four chromosomes in each of the daughter cells.
   - **Procedure question e**: The cells are identical.

2.
   - **Procedure question f**: The two strands of yarn are the same length and colour.
   - **Procedure question g**: The diploid chromosome number is four.
   - **Procedure question h**: During meiosis the homologous chromosomes line up along the equatorial plate; however, during mitosis the double-stranded chromosomes line up along the equatorial plate.
   - **Procedure question i**: Crossing-over, in which genetic information is exchanged, may occur during synapsis.
   - **Procedure question j**: The haploid chromosome number is two.
   - **Procedure question k**: Mitosis always produces two identical daughter cells, while meiosis produces four haploid daughter cells.

Section 2: Activity 3

1. a. One pair of homologous chromosomes did not separate but instead the entire tetrad was pulled to one pole. This process is called nondisjunction.

b. A normal gamete would look like the cell to the right.

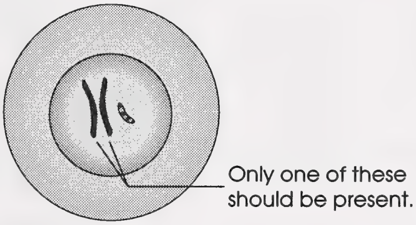


2. Three genetic disorders are Down syndrome, Klinefelter syndrome, and Turner syndrome. There are many others.

3. a. Nondisjunction has occurred in Division I.

   b. The egg cell shown has one too many chromosomes.

   c. Yes, it would be abnormal because it would lack one of the chromosomes that make up the set of twenty-three. It would be lacking some of the genetic information needed for the potential offspring to develop normally.



4. Monosomy is a condition in which only one chromosome of a particular type occurs instead of the usual pair.
   Trisomy is a condition in which three copies of a particular chromosome occur instead of the usual pair.

5. Situation A represents trisomy and Situation B represents monosomy.

6. a. Initially incidence of Down syndrome was linked to the mother's age.

   b. Radiation was found to cause nondisjunction in fruit flies.

   c. Dr. Uchida hypothesized that older women have been exposed to radiation over a longer period of time and so experience more nondisjunction.

7. The karyotype of a Down individual has one extra chromosome number 21 (trisomy 21), whereas there is a pair of this chromosome in a normal person.

8. Symptoms of Down syndrome include a round face, enlarged tongue, short height, large forehead, and often mental retardation. Most Down individuals do not live past the age of forty.

9. The incidence of Down syndrome increases dramatically if the mother is more than forty years old.

10. a. trisomic female b. Turner syndrome c. Klinefelter syndrome d. Turner syndrome

11. The sex of the person is male because the presence of the Y chromosome produces maleness regardless of the number of X chromosomes present.

12. The methods used to detect genetic disorders related to abnormal chromosome counts are the following:

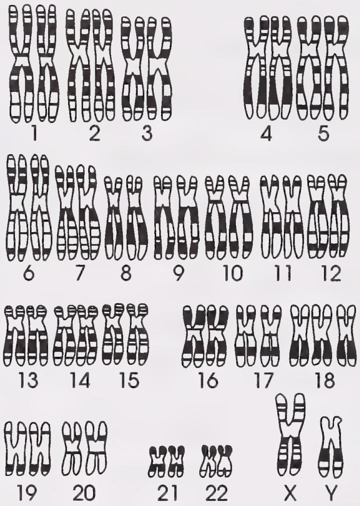
    - Ultrasound techniques locate the position of the fetus in the womb so that extraction of the fetal cells from the fluid surrounding the fetus can be done safely.

- The cells and fluid are extracted with a large syringe in a process called amniocentesis. These fetal cells are isolated and stained to make the chromosomes more visible. Chromosomes are karyotyped to find out if the chromosome count is normal.

- A technique called chorionic villus sampling draws cells from the outer membrane surrounding the embryo for analysis of the chromosomes present in the embryo cells.

13. A possible viewpoint may be that amniocentesis and other techniques should be used only for detection of genetic abnormalities in the fetus early in the pregnancy. The decision to continue with the pregnancy or to terminate it must be made by the parents.

14. Karyotype A should look like this.



15.
- **Procedure question a**: Chromosomes are arranged in pairs on the basis of the banding patterns, the size and shape of the chromosomes, and the location of the centromere.

- **Procedure question b**: Chromosome number 2 is larger, has its centromere in a different place along its length, and has a distinctly different banding pattern.

- **Procedure question c**: The sex is male because a Y chromosome is present.

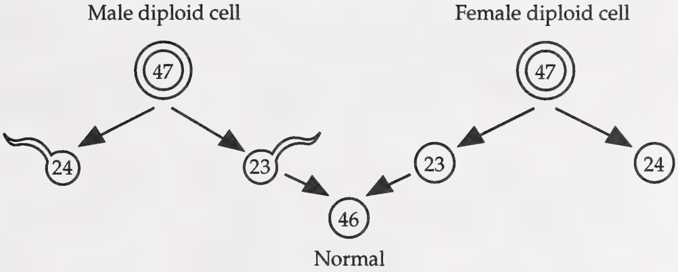
- **Procedure question d**: There are 47 chromosomes.

- **Procedure question e**: The sex is male.

- **Procedure question f**: Karyotype A shows that the individual has a genetic condition called Edward syndrome because there are three number 18 chromosomes.

- **Application question 1**: No, not necessarily. It may be that nondisjunction occurred in mitosis producing the one cell with one X chromosome. Many body cells taken from various places must show the Turner's syndrome karyotype to conclude that the individual displays a genuine Turner's condition.

- **Application question 2**: Yes it is possible for two Down syndrome individuals to have a normal child. When the homologous chromosomes line up along the equatorial plate during meiosis I, one cell will inherit two chromosome 21, the other one. If the normal cell containing one chromosome 21 combines with another normal cell from the other parent, the child will have the normal diploid chromosome number. The diagram will help to visualize what can happen.



- **Application question 3**: Yes, a baby with forty-eight chromosomes is possible if nondisjunction took place in both stages of meiosis or if nondisjunction occurred in both gametes. There are females with four X chromosomes plus the normal forty-four autosomes. Also, males have been identified with the XXXY set chromosome combination giving them a chromosome count of forty-eight.

- **Application question 4**: The gene for colour blindness is on the X chromosome. Like males, the Turner syndrome female has only one X chromosome.

Section 2: Activity 4

1. Budding involves mitosis because the bud is genetically identical to the original cell.
2. Four ascopores are produced. This is consistent with the results of meiosis because four cells are produced by this process.
3. Part A is the asexual phase and Part B is the sexual phase.
4. Unsuitable conditions appear to trigger sexual reproduction.
5. Conjugation produces new combinations of genes, increasing variability in individuals of a species.
6. Paramecia generally reproduce by binary fission.
7. The fusion of the nuclei to form a zygote represents the beginning of the sexual phase.
8. This is equivalent to fertilization.
9. The haploid condition is restored by meiosis.
10. Mitosis is involved in production of gametes because the cells of the plant are already haploid so meiosis cannot occur, nor does it need to.
11. Meiosis occurs in the capsule of the sporophyte, producing haploid spores.
12. The sperm must swim to the egg through a film of water.

13. Spores are resistant to dryness and can survive harsh conditions during dispersal.

14. The dominant stage is haploid.

15. a. sporophyte
    b. diploid
    c. spores
    d. meiosis
    e. haploid
    f. gametophyte
    g. gametes
    h. sporophyte

16. Pollen grains protect the sperm cell during transport from the anther to the pistil of the flower.

17. The disadvantage is that all the offspring are genetically similar to the original parent.

18. The flower produces nectar, a sweet juice that insects can eat. Shape and colour also attract insects.

19. Seeds are dispersed by wind, water, and organisms.

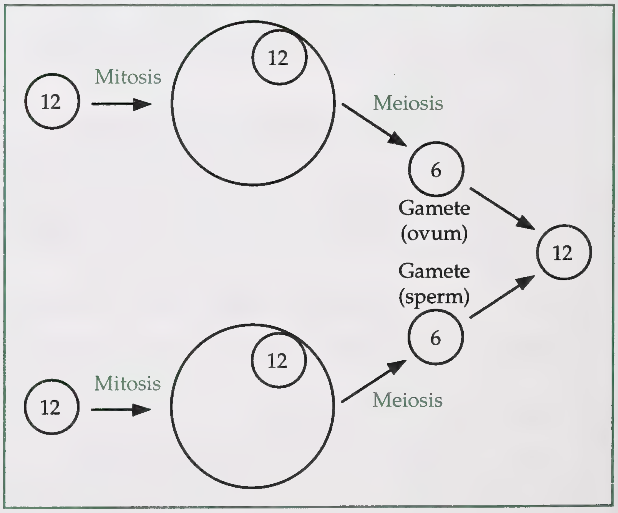
20. Having two sets of chromosomes gives the complex organism a duplicate set of genetic instructions so if a flaw exists in one set, the other provides a backup. This increases the chance that the individual will be normal.

21. The advantage is that the population growth can be more rapid.

Section 2: Follow-up Activities

Extra Help

1. It is vital to recognize that mitosis produces cells with the same chromosome number and meiosis produces cells with half the number of chromosomes.



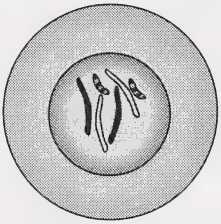
2. a. meiosis
   b. egg or ovum
   c. homologous
   d. interphase
   e. tetrad
   f. crossing-over
   g. replication
   h. anaphase I
   i. haploid
   j. cytokinesis
   k. spermatogenesis
   l. primary oocyte
   m. X and Y
   n. nondisjunction
   o. somatic cells
   p. gametophyte
   q. alternation of generation
   r. hermaphroditic

3. a. The phases shown are

i. metaphase I	iv. prophase I	vii. anaphase I
ii. interphase	v. prophase II	viii. telophase II
iii. anaphase II	vi. metaphase II	ix. early prophase I

b. ii, ix, iv, i, vii, v, vi, iii, viii

4. The cell would show the chromosome content as shown.



5.

Comparison of Mitosis and Meiosis

Type of Cell Division	Number of Cells Produced		Number of Chromosomes in Daughter Cells	Place of Occurrence in the Body
	Male	Female		
Mitosis	2	2	56	somatic or body cells
Meiosis	4	1	28	gonads, ovaries/testes

6. a. The new combination of genes would be brown hair and blue eyes and blond hair and brown eyes. These combinations would not be possible if crossing-over did not occur.

b. Crossing-over produces new combinations of traits which increases variations among individuals of a species.

7. a. A photograph of a person's chromosomes is called a karyotype.

b. The genetic anomaly is Klinefelter syndrome because the individual has extra sex chromosomes (X). This would occur as a result of nondisjunction of the X chromosomes during egg or sperm formation.

c. The sex is male because the Y chromosome is present. The genes on the Y chromosome always produce male characteristics regardless of the number of X chromosomes present.

8. a. Process X is meiosis, Process Y is mitosis, and Process Z is fertilization.

b. Mitosis gives rise to gametes because the cells of the plant in each case are already haploid.

c. Cycle B is more representative of the higher plants because the dominant stage is diploid and the gametophyte stage is small.

d. The gametophyte is dominant.

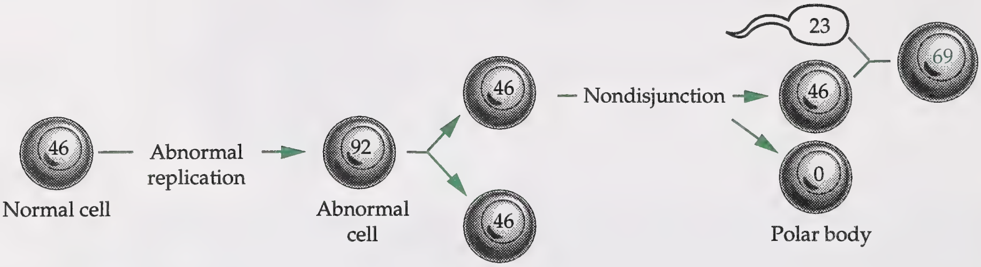
e. Cycle B shows a true alternation of generation because both the sporophyte and gametophyte stages exist, whereas only the gametophyte stage is evident for most of Cycle A.

f. The structures would be the pollen grain and the ovule.

Enrichment

1. Normal humans have two sets of chromosomes for a total of forty-six. This boy has twenty-three extra chromosomes that he must have gotten from one of his parents as a result of nondisjunction. This can be summarized with the help of a chart.

Assuming Nondisjunction in the Mother



If the egg carrying two sets of chromosomes is fertilized by a normal sperm, a triploid zygote is formed which carries sixty-nine chromosomes. Amazingly, this zygote developed because abnormal chromosome numbers in animals, including humans, are generally nonviable.

2. a. Polyploidy means many sets of chromosomes. Polyploidy in plants is common and occurs through natural nondisjunction methods, but this condition is rare in animals. A polyploid plant has at least four sets of chromosomes and is a hybrid of two different varieties or even two different species of plants. For example, a tomato has a haploid number of twelve chromosomes. Some species of tomato have 36, 48, and even 144 chromosomes. All of these are polyploids of the twelve chromosome plant. All are considered a different species because they breed true and each has its own distinct characteristics. Although polyploids can occur naturally as occurred with wheat, they are induced with the use of a chemical called colchicine which prevents separation of chromatids during mitosis. Seeds soaked in a solution of colchicine will produce plants with cells containing four sets of chromosomes. Gametes produced from these cells have a double set of chromosomes producing zygotes that are tetraploids. Using this technique, sterile hybrids such as the radish and the cabbage cross, can be made fertile by doubling the chromosome count. This generates homologous pairs that were missing and which are needed for tetrad formation during meiosis.

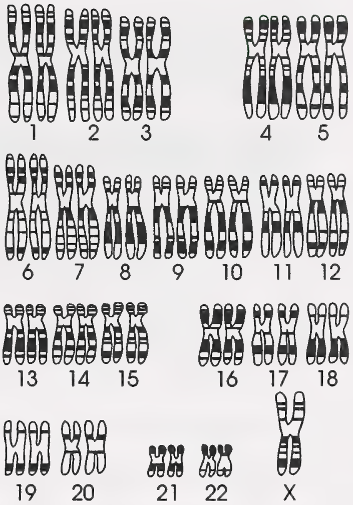
   b. Many plants, including wheat, oats, peanut, coffee, cotton, strawberry, and apple, are polyploids.

3. a. The particular nondisjunction could occur during spermatogenesis such that one sperm is formed with two Y chromosomes. This sperm then must fertilize a normal ovum.

   b. The environment is now accepted as a much more important factor.

4. Your karyotype should look similar to the one on the right.

   Notice there are only forty-five chromosomes. One of the sex chromosomes is missing. The single X chromosome would cause Turner syndrome in this female individual.



Section 3: Activity 1

1. The Chinese used their understanding of inheritance to select for desired traits in rice and the Babylonians used it to breed champion horses.

2. Aristotle believed that factors of inheritance existed in the blood. This is why even today there is reference to good bloodlines for well-bred animals.

3. Gregor Mendel's work with peas explained the mechanism of gene inheritance in plants and provided the foundation for the understanding of heredity in all organisms. That's why he is called the "Father of Genetics."

4. Mendel used garden peas for the following reasons:

   - They showed distinct contrasting variations of several traits such as tallness and shortness.
   - Pollination could be easily controlled by self-pollination or cross-pollination.
   - They were readily available and easy to grow.

5. Mendel studied seed shape, seed colour, pod shape, pod colour, flower colour, flower position, and stem length.

6. You probably predicted that the offspring would be of intermediate size.

7. He probably made the same prediction since the prevailing opinion at the time was that crossing two organisms with contrasting features produced intermediate types.

8. One possibility is to cross the offspring with short plants or with tall plants. Another is to cross the offspring with one another.

9. The ratio of tall plants to short is approximately 3 tall to 1 short. This is a very important observation.

10. Dominant refers to the factor or gene that expresses itself in the hybrid, whereas recessive refers to the factor or gene that is suppressed when both are present.

11. The principle of dominance explains that one factor of a pair masks the effects of the other in a hybrid. In hybrid peas the factor for tallness masks the expression of the factor for shortness.

12. A hybrid is an organism in which factors for a particular trait are not the same as in the parents.

13.

Results of Mendel's Crosses Where Parents Differed Only in One Trait	
Trait of Parent	**Trait of F_1's**
round × wrinkled seeds	round
yellow × green seeds	yellow
purple × white flowers	purple
green × yellow pods	green
inflated × constricted pods	inflated
axial × terminal flowers	axial

14. There appear to be two factors for each trait, one for each of the contrasting types.

15. No, they do not but Mendel assumed it was only one pair.

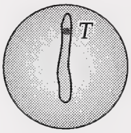
16. For each of the traits Mendel studied, one of the factors is expressed in the hybrid while the other disappears. The one expressed appears to dominate the other trait.

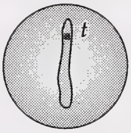
Section 3: Activity 2

1. In diploid organisms such as peas, chromosomes come in pairs, so genes for traits come in pairs as well.

2. They are called alleles.

3.



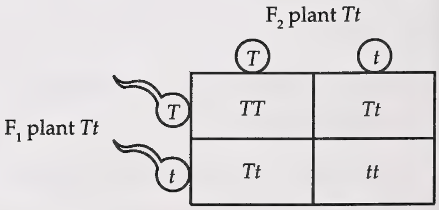


4. a. The term *genotype* can be translated into "type of genes" present in an individual and is represented by a set of letters such as *TT*. The phenotype refers to the outward appearance of the individual for a particular trait such as tallness.

   b. Identical alleles could produce one phenotype such as *TT* creating tall plants. *TT* is homozygous. Non-identical alleles where one is dominant would produce the same phenotype such as *Tt* also creating a tall plant. *Tt* is heterozygous. Both *TT* and *Tt* produce tall plants.

5. a. phenotype b. genotype c. segregation

6. a. Both parents are of the genotype *Tt*. The genotypes of the offspring are given in the square to the right. You will learn more about these squares later.



   b. The proportion of offspring that would be short is 1/4 or 25%.

   c. The percentage that are pure-breeding tall is 25%. Fifty percent are hybrid.

   d. The genotype is *tt*.

7.

Results of Mendel's Crosses Where Parents Differed Only in One Trait			
Parent Phenotypes	**F_1**	**F_2**	**F_2 Ratio**
tall × short	all tall	787 tall; 277 short	2.84:1
round × wrinkled seeds	all round	5474 round; 1850 wrinkled	2.96:1
yellow × green seeds	all yellow	6022 yellow; 2001 green	3.01:1
purple × white flowers	all purple	705 purple; 224 white	3.15:1
green × yellow pods	all green	428 green; 152 yellow	2.82:1
inflated × constricted pods	all inflated	882 inflated; 299 constricted	2.95:1
axial × terminal flowers	all axial	651 axial; 207 terminal	3.14:1

8 a. There was no evidence of blending for any of the traits.

b. The ratio is approximately 3:1.

9. Such crosses are called monohybrid crosses.

10. There is no difference in phenotype, the seeds of both will be round. The difference is in their genotypes: a homozygous round has two factors for round seed shape *RR*, whereas a heterozygous plant has one factor for round and one for wrinkled *Rr*.

11. a. homozygous b. heterozygous c. homozygous

12. A heterozygous plant has one gene for round seed shape and one for wrinkled. Because the gene for round is dominant the plant cannot produce wrinkled seeds. Wrinkled peas can only be homozygous recessive.

13 a. 50% to 50% b. 75% to 25% c. 0% to 100%

14.

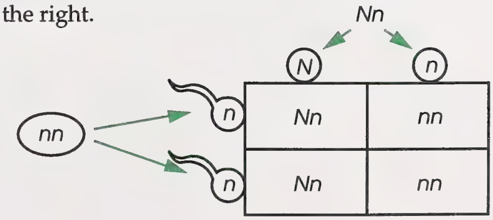
Tall Plant (homozygous or heterozygous)		Short Plant (homozygous recessive)	Genotype of F_1's	Phenotype of F_1's
TT: homozygous	crossed with	*tt*	All are *Tt*.	All are tall.
Tt: heterozygous	crossed with	*tt*	50% *Tt* 50% *tt*	50% tall 50% short

15. a. The genotype of the silky feathered bird is *nn* and that of the heterozygous bird is *Nn*. It doesn't matter which one is male or female.

b. The genotypes of the offspring are shown in the table on the right.

The offspring with the phenotype of *Nn* will have normal feathers and those with the genotype of *nn* will have silky feathers.

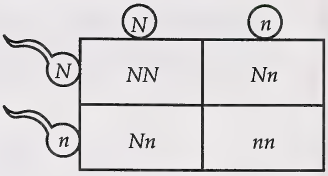
c. The phenotypic ratio is 1 normal to 1 silky.



	N	n
n	Nn	nn
n	Nn	nn

d. The results of a cross between heterozygous birds would give the following expected results.

Because the proportion of offspring that should be homozygous normal *NN* is 1 in 4 or 25%, the number of such birds out of 200 will be 50. The expected proportion of silky feathered birds *nn* is also 1 in 4 or 25%; 25% of 200 is 50 birds. The other 100 birds would be heterozygous normal.



	N	*n*
N	*NN*	*Nn*
n	*Nn*	*nn*

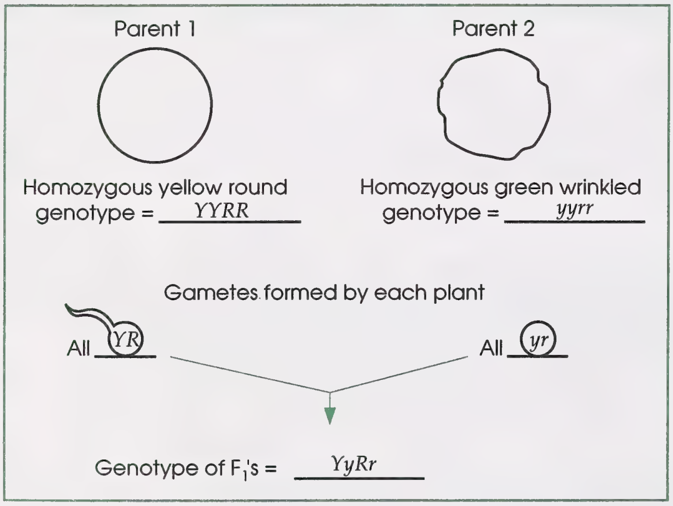
Section 3: Activity 3

1. He would be able to determine which colour and which type of hair is dominant because only those dominant traits would appear in the first generation.

2. The possible phenotypes would be black short hair, black long hair, white short hair, and white long hair. The order of these is not significant.

3. A dihybrid cross involves the inheritance of two traits at the same time, whereas a monohybrid cross involves the inheritance of only one trait.

4.



Parent 1

Homozygous yellow round genotype = *YYRR*

Parent 2

Homozygous green wrinkled genotype = *yyrr*

Gametes formed by each plant

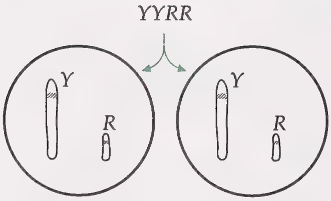
All *YR*

All *yr*

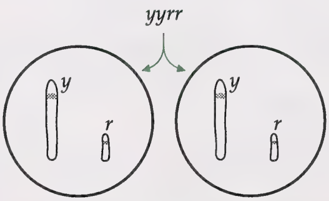
Genotype of F_1's = *YyRr*

5. The F_1 plant phenotype is yellow round.

6.



Gametes

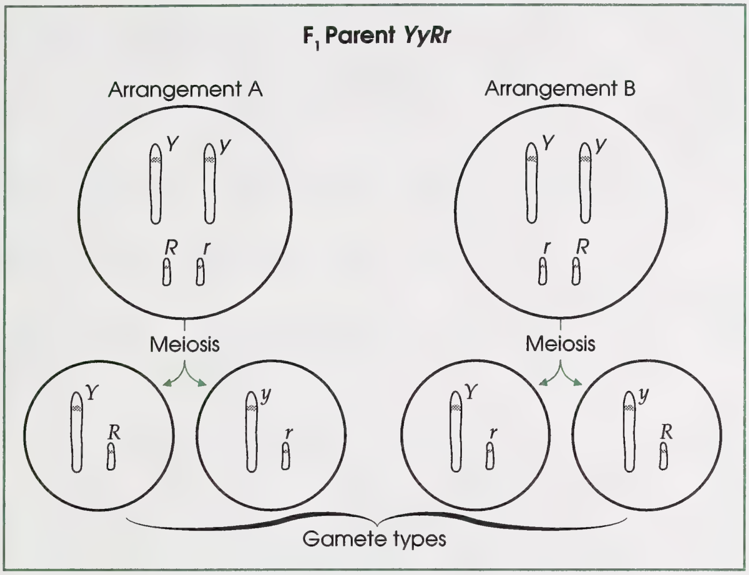


Gametes

7. He got four different phenotypes which is the same as what Derek got with his guinea pigs.

8. a. 9 yellow round b. 3 green round c. 3 yellow wrinkled d. 1 green wrinkled

9.



10. The Law of Independent Assortment states that genes for different traits assort or separate independently of one another. Another way to state it is the segregation of one pair of alleles or genes is not influenced by the segregation of another pair for another trait. This law only applies to situations where the two pairs of genes are found on different pairs of chromosomes.

11.

	YR	*Yr*	*yR*	*yr*
YR	*YYRR*	*YYRr*	*YyRR*	*YyRr*
yR	*YyRR*	*YyRr*	*yyRR*	*yyRr*
Yr	*YYRr*	*YYrr*	*YyRr*	*Yyrr*
yr	*YyRr*	*Yyrr*	*yyRr*	*yyrr*

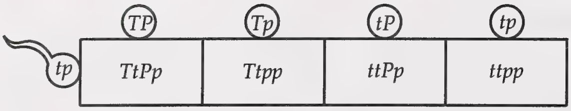
12. a. The genotypes that produce plants showing both dominant traits are *YYRR*, *YyRR*, *YyRr*, and *YYRr*.

b. 1/16 of the F_2's are *YYRR*.

c. 1/16 of the F_2's are *yyrr*.

13. a. Heterozygous plant = *TtPp*; gametes = *TP*, *Tp*, *tP*, and *tp*

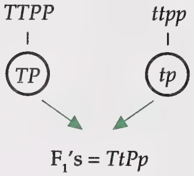
Homozygous plant = *ttpp*; gametes = *tp* b.



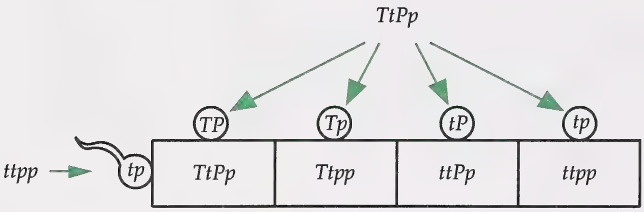
	TP	*Tp*	*tP*	*tp*
tp	*TtPp*	*Ttpp*	*ttPp*	*ttpp*

c. The genotypic ratio is 1(*TtPp*): 1(*Ttpp*): 1(*ttPp*): 1(*ttpp*). The phenotypic ratio is 1 tall purple : 1 tall white : 1 short purple : 1 short white. This could also be expressed as 1/4 : 1/4 : 1/4 : 1/4.

14. Perform the test cross to determine whether the plant is a hybrid or pure-breeding for both traits. If the plant is homozygous dominant *TTPP*, then all the offspring will be tall purple flowered *TtPp* when crossed with a homozygous recessive *ttpp*.



If the plant is heterozygous for both traits then some of the offspring will show recessive traits.



	TP	*Tp*	*tP*	*tp*
tp	*TtPp*	*Ttpp*	*ttPp*	*ttpp*

Notice that three of the offspring will show a recessive trait.

Section 3: Activity 4

1. a. Probability is the study of the outcomes of events or occurrences.

   b. The textbook expresses probability as a fraction.

   c. It could also be expressed as a percentage or as a ratio.

2. a. One chance in two, 1/2, or a 50% chance

   b. One chance in two, 1/2, or a 50% chance

3. You should get five heads and five tails. Your results could vary to the extreme of having all heads or all tails!

4. It should have been closer to 50/50 when the coin was tossed fifty times. 50/50 can also be expressed as 1:1.

5. The generalization is that the greater the number of times an event occurs, the closer the actual results will come to the predicted results.

6. a. Two heads should come up 12 times; 1/2 × 1/2 × 48 = 12.

   b. A head and a tail should come up 24 times; 2 × 1/2 × 1/2 × 48 = 24.

c. Two tails should come up 12 times; $1/2 \times 1/2 \times 48 = 12$.

7. To get the actual results even closer to the predicted, toss the coins more times.

8. a. The product rule states that the probability of two independent events occurring simultaneously is equal to the product of them occurring separately.

   b. Since the chance of getting a head on any toss is 1/2, the probability of heads coming up three times in a row is $1/2 \times 1/2 \times 1/2 = 1/8$ (1 chance in 8).

9. Yes, Mendel's results conform with the ratios shown in the investigation.

10. Treat dihybrid crosses as if they were monohybrid crosses. Multiply the chances of the two events occurring independently to determine the chance of them occurring together.

11. The chance of inheriting a straight hairline is 1/4 and so is the chance of inheriting attached earlobes. The chance of having a girl is 1/2, so the probability of all three of these traits occurring together would be $1/4 \times 1/4 \times 1/2 = 1/32$.

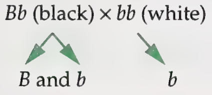
12. a. Since their first child is Rh^- this means that both parents must be heterozygous (Rh^+ Rh^-) for this blood type.

    The chance of their next child being Rh^- is 1 chance in 4 since the child must get two factors for the trait (Rh^- Rh^-).

	Rh^+	Rh^-
Rh^+	Rh^+Rh^+	Rh^+Rh^-
Rh^-	Rh^+Rh^-	Rh^-Rh^-

    b. The chance of the next child being a girl is 1/2 and the chance of it being positive is 3/4. Using the product rule, $1/2 \times 3/4$, the chance is 3/8 that the child will be a Rh^+ girl.

13. a. First work out the genotypes and phenotypes of the individuals involved.



	B	*b*
b	*Bb*	*bb*

or

Bb

bb

	B	*b*
b	*Bb*	*bb*
b	*Bb*	*bb*

The probability is 1 chance in 2 or a 50% chance white will occur.

    b. The predicted ratio of black to white offspring is 1 to 1.

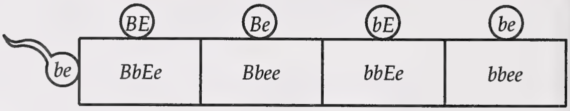
14. a. *Pp* and *Pp*

    b. *Pp* and *pp*

c. *PP* and *PP*, or *PP* and *Pp*. Both will produce 100% purple flowered offspring.

15. Crossing a dog heterozygous for both traits with a homozygous recessive dog would give the following results.

Heterozygous dog	recessive dog
BbEe	*bbee*



	BE	*Be*	*bE*	*be*
be	*BbEe*	*Bbee*	*bbEe*	*bbee*

a. The chances of them producing an offspring dominant for both traits is 1 chance in 4.

b. The chance of them producing a homozygous recessive is 1 chance in 4.

c. For a dihybrid cross, the chance of producing a homozygous recessive pup is 1 chance in 16.

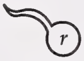
Section 3: Activity 5

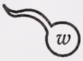
1. Pink flowers indicate that neither red nor white is dominant.

2. There is a subtle difference between the two. Codominance occurs when both alleles are expressed producing a mixture of the two phenotypes as is the case with grey and chocolate brown spots in cats or red and white hair on roan cattle. With incomplete dominance, both alleles are equally expressed and uniformly produce a blend of the two phenotypes such as pink colour of flowers in snapdragons.

3. a. *rr* b. *ww* c. *rw*

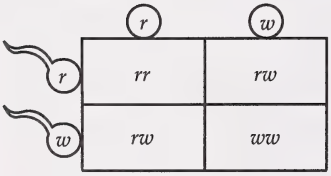
4. He would have not proposed the principle of dominance.

5. a. *rw* b. *rw* c. 

and 

d. ⓡ and ⓦ

e.

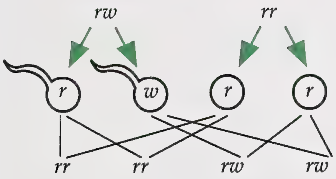


	r	*w*
r	*rr*	*rw*
w	*rw*	*ww*

f. The phenotypic ratio for a monohybrid cross with no dominance is 1:2:1, whereas it is 3:1 where dominance is involved.

6. Heterozygotes have distinct phenotypes such as pink or roan, making them easily recognizable. Heterozygotes produce two different kinds of gametes and therefore are not pure-breeding.

7.



or

		Red	
		r	r
Roan	r	rr	rr
	w	rw	rw

The chance of producing a red is 50%.

8. The breeding result of the cats cannot yet be fully explained but probably indicates some dominance and codominance occurring.
9. There are four alleles, one for each of the four colours, wild (red), apricot, honey, and white.
10. Every fly inherits only two alleles for eye colour.
11. The genotypes of red-eyed flies are E^1E^1, E^1E^2, E^1E^3, and E^1E^4.
12. The genotypes must be E^1E^4 and E^1E^4.
13. See the table in the background information of the Case Study on page 479 for the possible genotypes. If you have type AB or O blood, you can have only one genotype, but if you have type A or B blood, you could have two possible genotypes for each type.
14. The genotype of both parents must be I^AI^O for two reasons. Each must have an allele for blood type A to have type A blood and they must each contribute an allele I^O to the offspring with blood type O (I^OI^O).
15. Beth was the murderer! The murderer must have blood type O, Rh negative. The suspects are Henry, Tom, and Beth. Henry refused to give a blood sample, but since his parents lack freckles he would not have them either so he can be eliminated. Like Henry, Tom does not have freckles, but he is not actually the son of Lord Hooke because he has blood type O, an impossibility if his father (Lord Hooke) has blood type AB. Tom's daughter Beth has the right blood type and likely has freckles, a trait she inherited from her mother who has also passed on the gene for this trait to Beth's sister Tina.

Section 3: Follow-up Activities

Extra Help

1. Some characteristics seemed to be blended out of a species only to reappear in a new generation. Darwin's theory could not explain where the characteristics went.
2. Mendel could have predicted the offspring would exhibit a characteristic inbetween round and wrinkled.
3. All the offspring were round.
4. Mendel crossed the hybrids.
5. The wrinkled peas reappeared along with round peas. The ratio of round to wrinkled peas was 3:1.
6. Two factors must exist for each characteristic or trait. Factors may be dominant or recessive so combinations may be dominant-dominant, dominant-recessive, or recessive-recessive.

7. Pure wrinkled *rr*

Pure round *RR*

	r	*r*
R	*Rr*	*Rr*
R	*Rr*	*Rr*

New generation is *Rr*.

8. The hybrids will appear round.

9. preserved

10. genes

11. allele

12. phenotype

13. genotype

14. The basic question asks where new variations come from. The answer lies in variation produced by cross-over, nondisjunction, and mutation followed by sexual reproduction.

15. Factors (genes) survive intact from generation to generation, preserving traits which will appear in fixed mathematical proportions. A common ratio is 3:1.

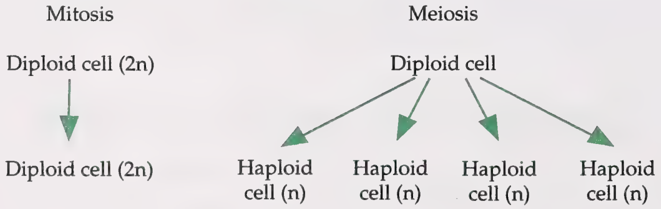
16. Although genes preserve traits from generation to generation, variation occurs as some traits appear or disappear. Changes in the environment may periodically favour one trait over another. For a time this particular trait or phenotype will survive while others perish and be found in greater numbers in population.

17. Variation required a knowledge of meiosis and sexual reproduction.

18. Mitosis creates identical copies of cells in terms of chromosome numbers. The 2n number of chromosomes will be repeated. If gametes had 2n chromosomes, then fertilization would result in 4n. Genetic material would continually increase.

19. The number of chromosomes must be split in the formation of gametes so when gametes join in fertilization the original number will be restored.

20.



21. random assortment

22. *RTD*
RTd
RtD
Rtd
rTD
rTd
rtd
rtD

Any of these combinations could form.

23. Over 8 million combinations exist.

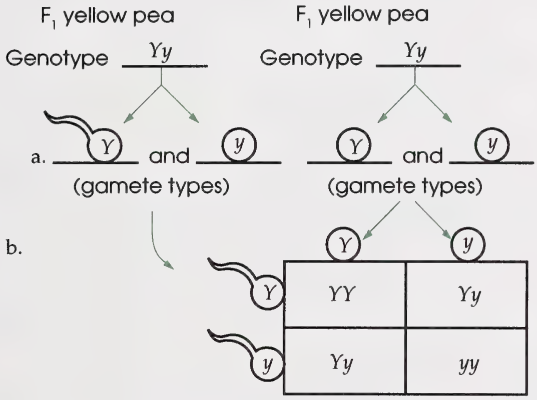
24. Cross-over tremendously increases variation.

25. The result is evolution.

26. a. phenotype
b. genotype
c. phenotype
d. genotype

27. a. fertilization
b. factor
c. blending
d. *RrYy*
e. 3:1
f. *AB*, *aB*
g. *TTPp*
h. 9:3:3:1
i. chance
j. product rule

28.



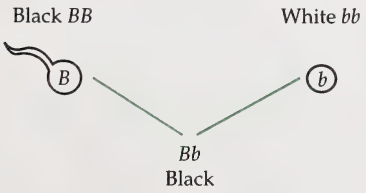
c. 3/4 yellow and 1/4 green

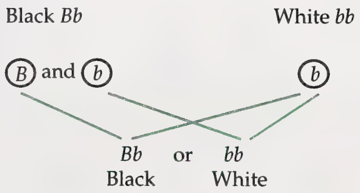
29. a. *BB*
b. *bb*
c. The phenotype is black.

d. You could cross it with a white sheep.

If the black sheep is homozygous *BB*, all the offspring will be black.

If the black sheep is heterozygous *Bb*, then when crossed with a white sheep *bb* some of the offspring will be white.





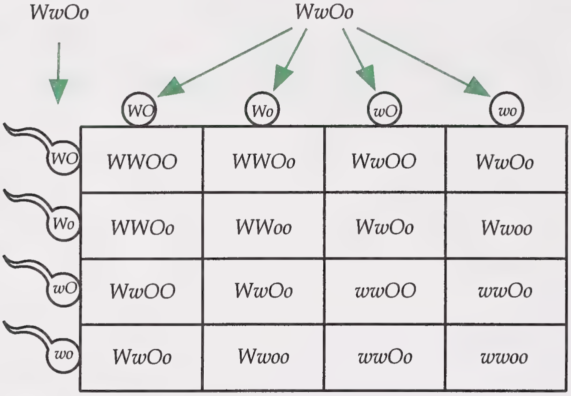
e. The best genotype would be *BB* crossed with *BB*.

30. a. It is a dihybrid cross.

b. The whiskered round schmoo produces *Wo* gametes, and the non-whiskered oval schmoo produces *wO* gametes.

c. The genotype of the F_1's is *WwOo*.

d.

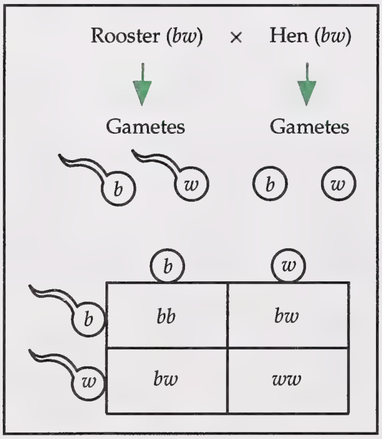


	WO	Wo	wO	wo
WO	WWOO	WWOo	WwOO	WwOo
Wo	WWOo	WWoo	WwOo	Wwoo
wO	WwOO	WwOo	wwOO	wwOo
wo	WwOo	Wwoo	wwOo	wwoo

The phenotypes are oval whiskered, oval non-whiskered, round whiskered, and round non-whiskered.

31. The rooster and hen must be heterozygous and the alleles for black and white must be codominant.

The following phenotypes are produced: *bb* = black; *bw* = blue; *ww* = white. Theoretically, 50% of the offspring should be blue phenotype.

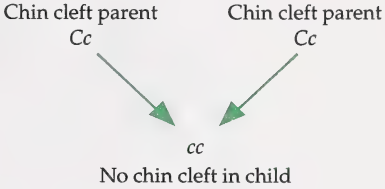


	b	w
b	bb	bw
w	bw	ww

Enrichment

1. a. No you cannot be absolutely certain. The genotypes of the parents could be *CC* and *CC*, *CC* and *Cc*, or even *Cc* and *Cc*. Your genotype could be *CC* or *Cc*.

   b. If one of your brothers or sisters do not have a chin cleft and your parents do, then you would know that your parents are both heterozygous. To be chin cleft, your parents must have at least one factor for it because the trait is dominant. To produce an offspring that does not have the dominant feature means that each parent must be carrying one recessive factor passing it on to the child without the chin cleft.



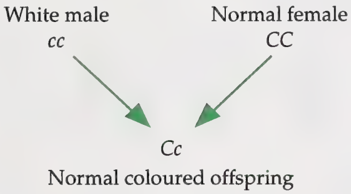
2. The genotype of a heterozygous individual will always be *Cc*.

3. It is difficult to imagine any adaptive value in any of these traits that would allow individuals to survive better.

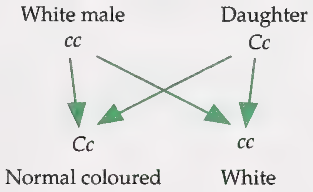
4. You cannot generalize by saying that the dominant trait is more common in every case. The more common feature, whether it is dominant or recessive, has been selected through the process of natural selection because it either has adaptive value or may be connected to other traits that do.

5. The male must be homozygous recessive *cc* for coat colour. Normal colour *C* is dominant to white *c*.

a.



b.

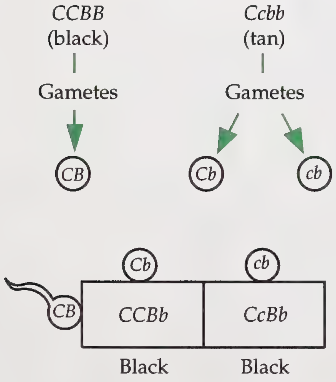


6. **Review question 12:** The two pairs of alleles involved are

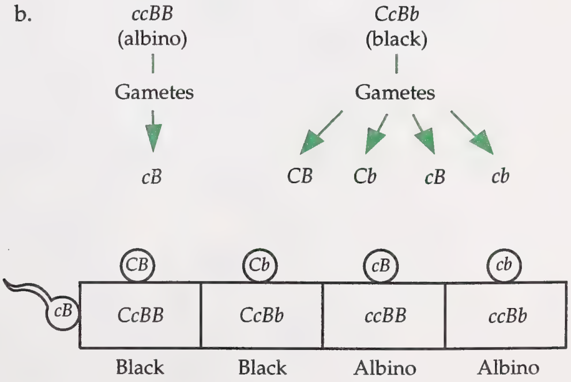
C – gene for pigment production;
c – allele for no pigment production;

B – gene for black coat colour
b – allele for tan coat colour

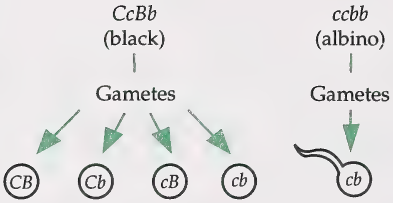
a.



b.

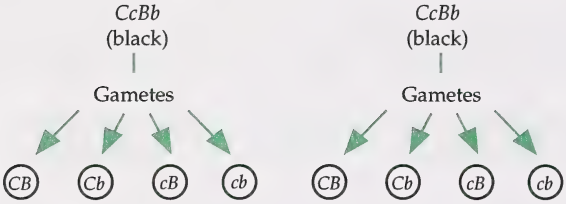


c.



	CB	Cb	cB	cb
cb	*CcBb*	*Ccbb*	*ccBb*	*ccbb*
	Black	Tan	Albino	Albino

d.

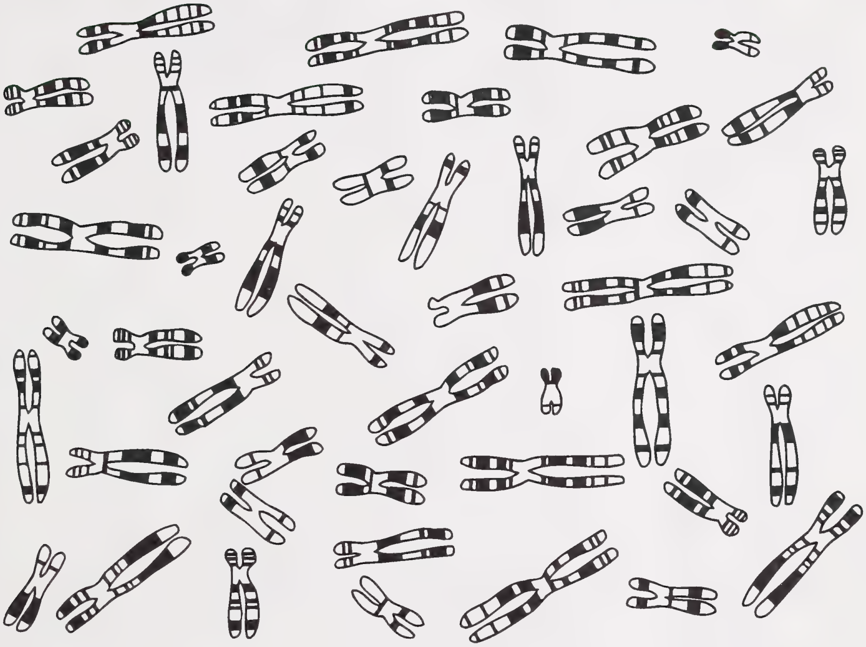


	CB	Cb	cB	cb
CB	*CCBB*	*CCBb*	*CcBB*	*CcBb*
Cb	*CCBb*	*CCbb*	*CcBb*	*Ccbb*
cB	*CcBB*	*CcBb*	*ccBB*	*ccBb*
cb	*CcBb*	*Ccbb*	*ccBb*	*ccbb*

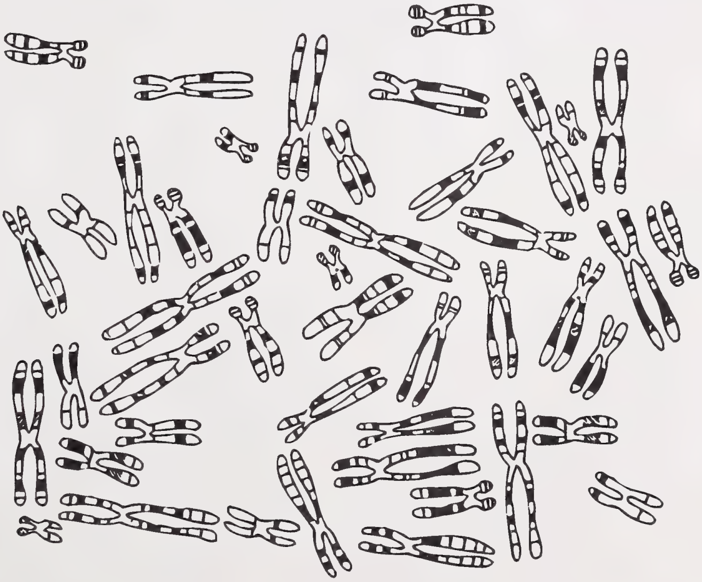
The phenotypic ratio is 9/16 black; 3/16 tan; 4/16 albino.

Human Karyotype Plates

Human Karyotype: Plate A



Human Karyotype: Plate B



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